MINING ENGINEERING

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Iron Ore Beneficiation

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Aluminum Therapy in Silicosis

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Effects of Rod Mill Speed

A MONTHLY PUBLICATION OF THE
AMERICAN INSTITUTE OF MINING AND METALLURGICAL ENGINEERS
MINING BRANCH

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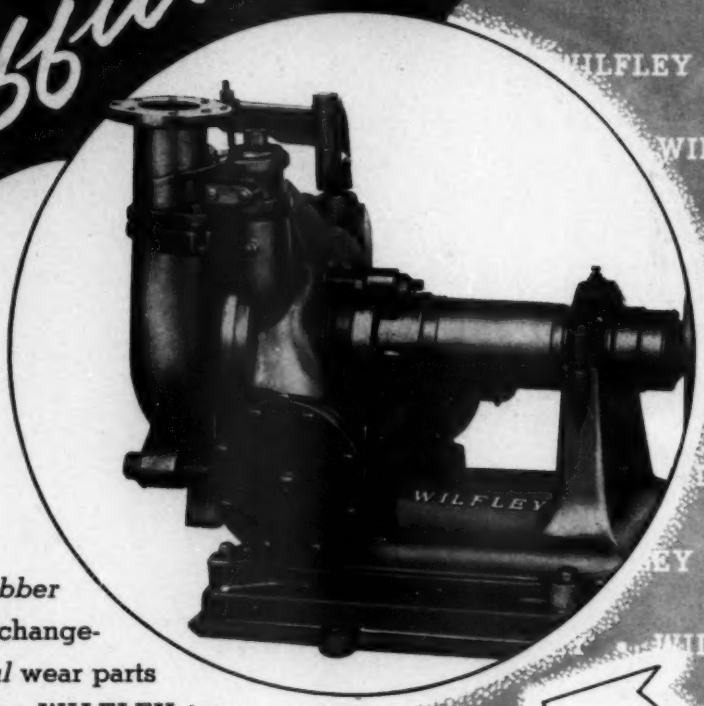
...for the EVER-*Efficient*



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WILFLEY *rubber* parts are interchangeable with *metal* wear parts ...one of many WILFLEY improvements and features that mean cost-reducing efficiency, reliability, stepped-up production and worthwhile power savings. In addition to rubber, WILFLEY wear parts are available in electric furnace iron and other materials individually engineered for cost-saving efficiency on the job. An economical pump-size for every purpose. Buy WILFLEY when reduced operating cost is prime consideration. *Write or wire for details.*

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centrifugal PUMPS

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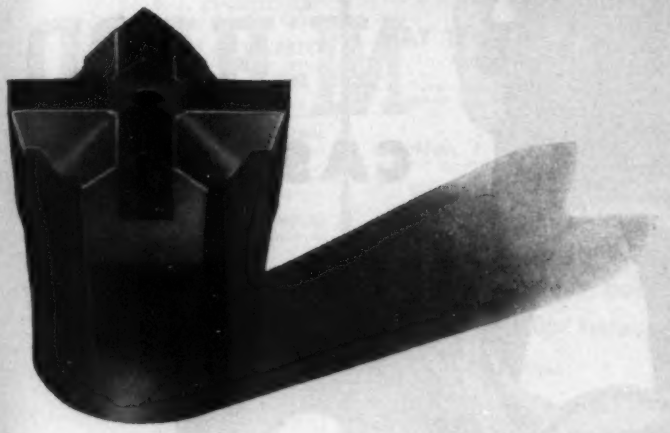
Drill faster, 50% or more
Boost tonnage 20% or better
Finish more rounds per month!



Now it has been Proved that you can do this, and much more, with the I-R CARSET JACKBIT

More than two years of actual field experience have given positive proof of what the CARSET JACKBIT can do – under all drilling conditions, in all kinds of rock. The results today are creating a complete revolution in rock-drilling performance and economy.

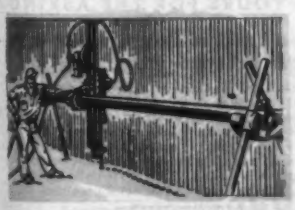
For here is a Carboloy-set bit that is repeatedly out-drilling and out-lasting a steel bit usage by 50-to-1, 100-to-1, and in many cases as much as 400-to-1! Uniformly high drilling speed is maintained for the full depth of the hole – without the progressive slackening in speed of quick-dulling steel bits. Bit changing is practically eliminated, longer steel changes can be used, and single-gauge holes can be drilled to any practical depth. This means more efficient drilling cycles, more rock or ore broken per shift – usually *20%* or more.

For the complete story on the CARSET JACKBIT, write today for your copy of our new 36-page, pocket-size catalog, Form 4091.

HERE ARE A FEW TYPICAL REPORTS ON CARSET PERFORMANCE

A MINING COMPANY, drilling in a very hard quartzite, reports that CARSET JACKBITS have so multiplied drilling speed that miners can now drill and blast on the same shift. With steel bits, blasting previously had to be done on the second shift. This customer has converted to CARSET JACKBITS 100%.

ON A LARGE DAM PROJECT, 2" CARSET JACKBITS were used with 4" Wagon drills operating in hard dense basalt. These bits drilled 24-ft. holes in 22 minutes, while steel bits previously used required 66 minutes for an 18-ft. hole (with 10 bit changes). Footage was increased from 120 to 261 ft. per shift.



IN A GRANITE QUARRY, CARSET JACKBITS have given such outstanding performance that steel bits are no longer used. Previously, with quick-dulling steel bits, the bit reconditioning shop had to be run two 8-hour shifts a day. This operation has now been almost eliminated.

A MINING COMPANY, in driving a 12 x 20 foot 97-hole heading in taconite, required an average of 49.8 hours to pull a 5-foot round. With CARSET JACKBITS they pulled 6½-foot rounds and cut this time to 18.5 hours. Accurate cost records showed a direct saving of $92.69 per foot of drift, or $602.48 per round.

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Ni-Hard is widely used to extend the life of mine equipment.

*Reg. U. S. Pat. Off.

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MINING ENGINEERING

in which is incorporated Mining and Metallurgy, Mining Technology and Coal Technology

MAY 1949 VOLUME 1, NO. 5

Cover photograph shows one of the eight rows of six five-turn spiral per row in the Hill-Trumbull spiral plant of the Cleveland-Cliffs Iron Co.

Section 1

EDITORIAL		13
IRON ORE BENEFICIATION	F. X. Tartaron	14
CENTRIFUGAL METHOD SPINS CONCRETE INTO PIPE	R. C. Mahon	19
ALUMINUM THERAPY CONQUERS SILICOSIS	J. W. G. Hannon and P. G. Bovard	20
GRADUATE STUDY RESTRICTED TO FEW SCHOOLS	J. D. Forrester	23
OPEN PIT FORUM	G. J. Ballmer and M. M. Stover	24
GOVERNMENT IN YOUR HAIR	R. W. Smith	26
COLORADO MINING ASSOCIATION MEETING	J. V. Beall	27

Letters to the Editor	29	Manufacturers News	43
Book Reviews	30	Professional Services	44
Personnel Service	42	Advertisers' Index	46

Section 2

To AIME Members	181	Current Institute Papers	187
Board of Directors' Meeting	182	Calendar of Coming Meetings	187
D. H. McLaughlin for President	184	Drift of Things	188
Where to Split Metallurgists	184	News of AIME Members	190
Student Society Reports	185	Obituaries	197
Local Section Notes	186	Membership	198

Mining Transactions

DRILLING AND SAMPLING UNCONSOLIDATED MATERIALS	L. W. Dupuy	125
EFFECTS OF ROD MILL SPEED AT TENNESSEE COPPER COMPANY	J. F. Myers and F. M. Lewis	131
TEMPERATURE COMPENSATION OF OLD TYPE ASKANIA MAGNETOMETERS	T. Koulomzine	133
MUNICIPAL WATER NEEDS VS. COAL MINE STRIPPING	G. M. Dexter	137
CORRELATION OF THE PERFORMANCE CHARACTERISTICS OF DOMESTIC STOKER COALS WITH THEIR CHEMICAL AND PETROGRAPHIC COMPOSITION	R. J. Helfinstine and G. H. Cady	159
READY-MADE HEAT FROM COAL	D. W. Loucks	164

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AIME also publishes Journal of Metals and Journal of Petroleum Technology.

Grinds 6,000,000 Tons in 19 Years: 16-20 Hours a Day

TAKES REAL TOUGHNESS to stand a long grind like this. Yet, after 19 years, this 9½ ft diameter, 3-compartment dry grinding *Compeb* mill is still going strong for a large cement company.

On the job 16 to 20 hours a day, this Allis-Chalmers mill reduces limestone and shale to a specification raw mix for a rotary cement kiln. Aside from routine liner and grinding media replacement, the mill has required only *one major repair*, a pinion and pinion shaft.

CHECK THESE STRENGTH FEATURES

Strength and stamina are built into every part of Allis-Chalmers *Compeb* mills.

- Bearings, for example, are extra large and equipped with flood lubrication . . . your assurance of low bearing pressure, long life.
- Mill shells are of all-welded construction, "stress-relieved" after welding to minimize strains.
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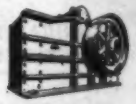
When you specify Allis-Chalmers for grinding mills you'll get a mill that's *well-suited to your specific grinding job*. A-C builds five separate types of grinding mills in a maximum range of sizes . . . with overflow, diaphragm grate or special discharge modifications . . . with feeder and drive to suit your mill size and application.

For sound advice on your grinding problems — based on A-C's experience in building *over 4,000* mills—call your nearby A-C representative. Offices or distributors in principal cities in the U.S. and throughout the world.

Compeb is an Allis-Chalmers trademark.

Kilns, Coolers, Dryers



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Hoists

Mills

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AND OTHER EQUIPMENT FOR THE CRUSHING, CEMENT AND MINING INDUSTRIES

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"King Size" Power-Shovel Bucket made of J&L HEAT-TREATED JALLOY STEEL still going strong after full year's gruelling service!

J&L STEEL

Performance record on this Marion No. 5561 power shovel proves high-impact and abrasion resistance of J&L heat-treated JALLOY
BIG SCOOP!

—40 CUBIC YARDS

of earth and rock in one "scoopful." This monstrous power-shovel bucket excavates 10 acres to a depth of 50 feet *in a month.*

Working *day and night* it removes overburden on a large strip mining operation in southern Illinois. As it digs its way through some 15 feet of limestone, 15 feet of shale and 20 feet of clay, it is subjected *continuously* to severe abrasion and impact.

Yet the J&L *heat-treated* JALLOY STEEL on the bucket *has given more than a year of service!*

To date more than 6,000,000 cu. yds. have been excavated, but the excellent appearance of the J&L heat-treated JALLOY STEEL indicates a reasonable expectancy of *many more* months of service before replacement is necessary.

J&L *heat-treated* JALLOY STEEL was developed for just such uses as this—where steel must withstand extreme abrasion and heavy shock for long periods of time. Its outstanding wear-resistant properties make it especially useful for Scrapers . . . Rock crushers . . . Bulldozers . . . Truck bodies . . . Dump cars . . . Chutes . . . Power-shovel buckets.

Wherever wear and abrasion are limiting factors in the life of equipment, you'll find it profitable to use J&L *heat-treated* JALLOY STEEL. May we send you the booklet mentioned in the coupon?

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From its own raw materials, J&L *manufactures a full line of carbon steel products, as well as certain products in* OTISCOLOY *and* JALLOY (*hi-tensile steels*).

PRINCIPAL PRODUCTS: HOT ROLLED AND COLD FINISHED BARS AND SHAPES • STRUCTURAL SHAPES • HOT AND COLD ROLLED STRIP AND SHEETS • TUBULAR, WIRE AND TIN MILL PRODUCTS • "PRECISIONBILT" WIRE ROPE • COAL CHEMICALS

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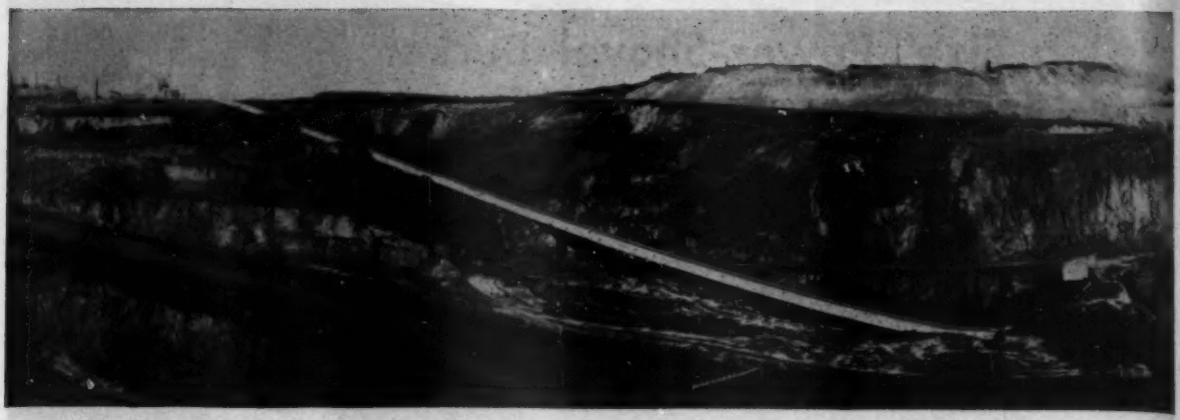
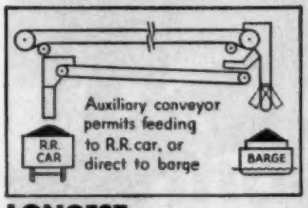


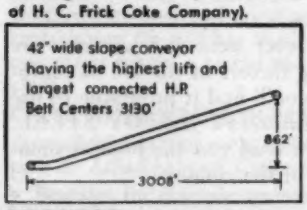
Above: 1700 ft. long belt conveyor in the mining industry. One of a number of Link-Belt slope belt conveyors installed on the iron range.

Why Link-Belt leads in belt conveyor engineering

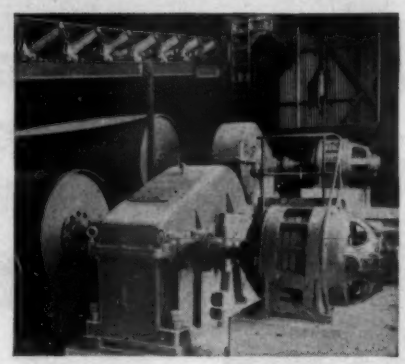


LONGEST belt conveyor in the mining industry (10,900 ft.) for a metallurgical coal mine in West Virginia.

WIDEST belt conveyor in the mining industry (72" belt), installed at the largest coal mine (Robena Mine of H. C. Frick Coke Company).



HIGHEST lift (862 ft.) in the mining industry for a Southern Illinois coal mine.



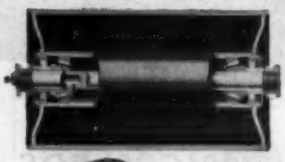
Terminal belt conveyor drive equipment at Robena Mine (above). The success of Link-Belt conveyor installations in raising production rates and cutting handling costs is due not only to the most advanced design and construction of Link-Belt manufactured components, such as carrying and return idlers, terminal and drive machinery, welded steel pulleys, and highly efficient speed reducers, but to broad engineering experience in integrating these elements most effectively.

LINK-BELT COMPANY

Chicago 9, Philadelphia 40, Pittsburgh 13, Wilkes-Barre, Huntington, W. Va., Atlanta, Dallas 1, Minneapolis 5, Denver 2, Kansas City 6, Mo., Los Angeles 33, San Francisco 24, Cleveland 15, Indianapolis 6, Detroit 4, St. Louis 1, Seattle 4, Vancouver, Toronto 8. 11,480

LINK-BELT *Belt Conveyor Idlers*

The Link-Belt "100" belt conveyor idler is the culmination of more than half a century of experience and development.



Illustrations above and to the left show the positive Grease-In-Dirt-Out Seal which conserves lubricant and prolongs bearing life . . . cross-section of roll, showing shaft, grease seals and roller bearings . . . tough malleable bracket in reinforced T-section to withstand load and impact.

Link-Belt positive action self-aligning troughing idler. For details on Link-Belt belt conveyor equipment, ask for Book 1915.

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Car Dumpers
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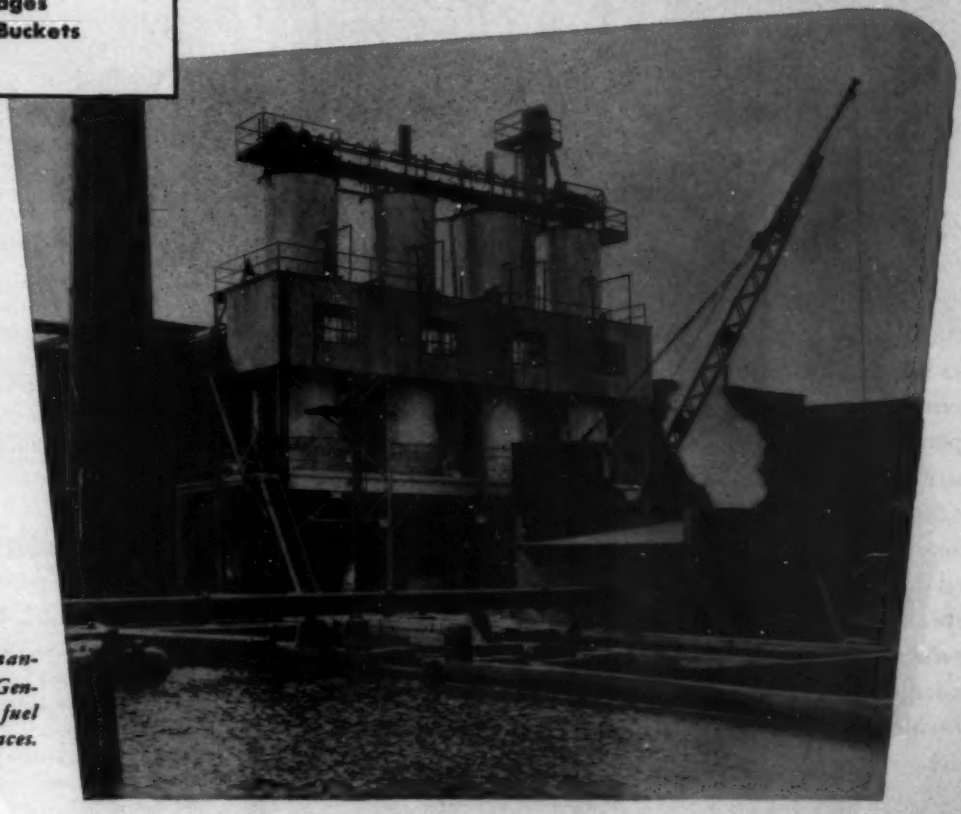
Mine Hoists
Skip Hoists
Ore Bridges
Clamshell Buckets

Wellman-Galusha Clean Gas Generators

Built exclusively by Wellman



Four 10 ft. Wellman-Galusha Clean Gas Generators supplying fuel for steel mill furnaces.

• Only Wellman builds the Galusha Clean Gas Generators that so ideally meet your requirements with efficiency and economy. These generators combine, in a *complete* machine, the rotary grates, ample fuel storage bin, and provisions for generating the steam required for making the gas. Even the lowest-priced grades of Anthracite and coke can be satisfactorily gasified.

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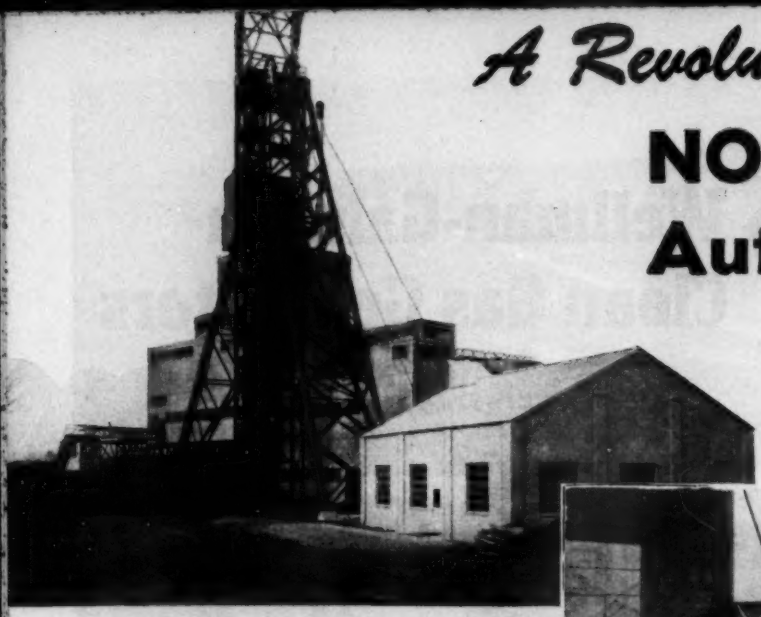
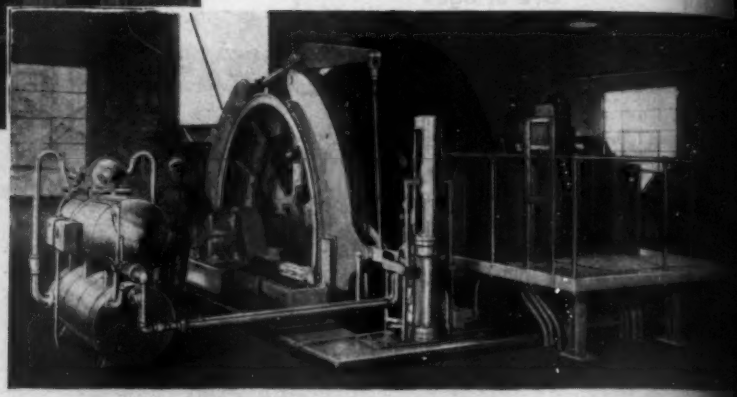
A Revolutionary

NORDBERG Automatic Hoist

at Snow Hill's Modern Mine





Nordberg Automatic Hoist installed at the Snow Hill Coal Corporation Green Valley Mine #2, near Terre Haute, Indiana. This hoist has a 9 to 16 foot diameter, double, cylindro-conical drum with skip and counterweight and is driven by 1250 HP DC motor.

The Nordberg fully automatic hoist recently placed in service at the Green Valley Mine #2 of the Snow Hill Coal Corporation is another of the many outstanding developments that Nordberg has made in the mine hoisting field. This hoist is fully automatic although it can be operated manually if desired. In automatic operation, the skip is loaded with 24,000 pounds of coal from the weigh pan, then raised to the top of the tipple and dumped, with the hoisting cycle being repeated every 62 seconds as long as there is coal available for hoisting. No operator is required either underground or on the surface. Positive safety devices provide protection against any contingency which may arise.

Duty Cycle of Snow Hill Hoist

700 tons of coal per hour maximum from lower seam.

710 ft. lift from lower loading point to dump.

12 tons of coal per skip.....24,000 lbs.

Skip, bail and rope.....23,800 lbs.

Offset by a counterweight of.....35,800 lbs.

Loading of skip from weigh pan completed in 5 seconds.

Skip accelerates to maximum speed in 5 or 6 seconds.

Skip reaches headframe in 16 seconds.

Skip pauses in dumping horns 4 seconds to allow lowering sequence to start.

A complete hoisting cycle every 62 seconds.

NORDBERG AUTOMATIC HOIST APPLICABLE TO METALLIC AND NON-METALLIC MINES

The Nordberg Automatic Hoist is applicable for either metallic and non-metallic mines, where continuous automatic hoisting is desired. Nordberg engineers will gladly help you determine whether automatic hoisting will be profitable for your operations and recommend the type of hoist best suited for the service. Write for detailed information today.

NORDBERG MFG. CO.
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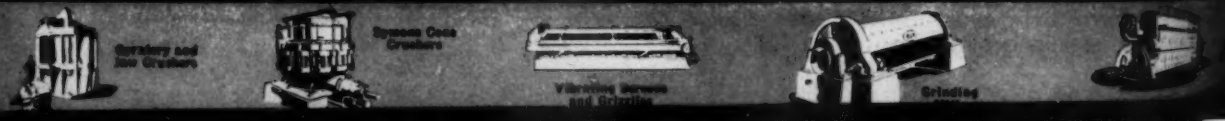
Machinery for processing ores and industrial minerals



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TRUCO DIAMOND DRILL BITS

by WHEEL TRUEING

This is the cover of the interesting and informative new 32 page catalog of TRUCO DIAMOND DRILLING PRODUCTS. May we suggest that you reserve your copy by writing to Wheel Trueing Tool Co., 3200 W. Davison, Detroit 6, Michigan.

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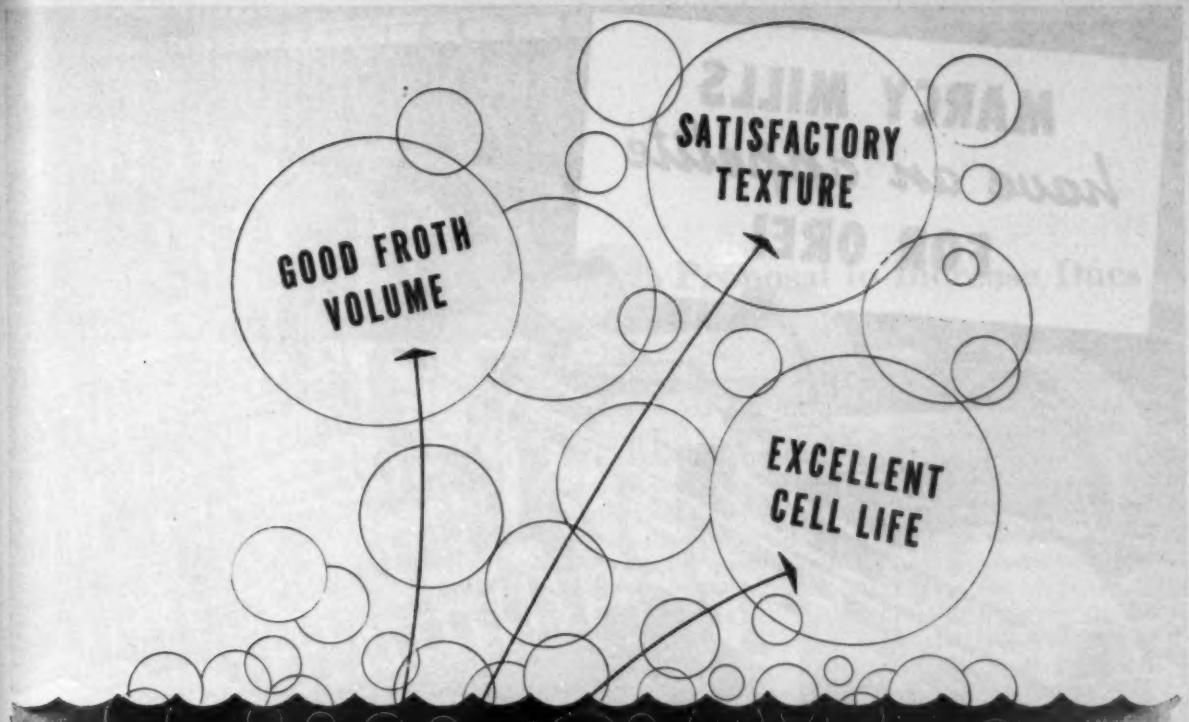

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The **Mine & Smelter** Supply Co.

MINING ENGINEERING

Proposal to Increase Dues

To ask a member of any organization whether or not he wishes to have his dues raised invites the obvious answer. It is the same answer he would be likely to give you if he were asked if he wished to have his taxes raised. However, in each case, *if the increased money thus supplied were used wisely*, the person might personally benefit by considerably more than the amount of the increased levy; in which case his answer should be "yes."

The American public has pretty well accepted practically a doubling in the price of many things in the last few years, food being a conspicuous and widely purchased example, automobiles another. A few things, such as rent, have increased comparatively little, being under government control, but those who furnish these services generally have been able to get by through continuing peak use of the facilities they provide. Combining all the important things that one has to buy, the Government tells us that the index of the cost of living last year was about 170, based on 100 for 1935-39, which means the purchasing value of the dollar dropped to 59 cents.

Everybody knows all about this. But the fact remains that it is only human to wish to hold one's expenses in check wherever possible, and conversely to increase one's income by such means as are available. Everyone would like to have the difference between his income and his absolutely necessary expenses as large as possible, so that he can have the maximum amount to do with as he likes, be it buying a few books, a television set, going to the theatre oftener, patronizing better restaurants, or maybe improving his brand of liquor.

Taxes one *must* pay, willy-nilly. Dues to the AIME one need not pay. One may drop his membership and pay nothing; or, if the majority so wills, continue to pay the same amount as at present with probable drastic reduction in publications; or, if the vote favors a $2 to $5 increase, pay from six to fifteen dollars more over the next three years. The return, however, will be considerably more than proportional. If a man who is active professionally invests from $25 to $50 per year annually in a membership in the AIME, a subscription to one or two other technical journals in his field, and a few of the new books on his specialties, he should get ideas and knowledge and friends worth hundreds or even thousands of dollars to him. There is just one stumbling block. Such an investment is worth much less or even nothing if one does not read the product purchased, or, in the special case of the AIME, if one also never goes to a meeting. In other words, one must use the service purchased. Even a new automobile is no good if it is always kept in the garage.

So let us say, in the case of a mining man, if he does not belong to the AIME, does not take the E&MJ or other technical journals, and never goes to a meeting, all he learns is what he acquires from his own personal experience, or from the small circle of men with whom he works. Meanwhile, others, more astute, are preparing themselves for better jobs.

As for the AIME, as with other similar professional societies, some of the money received from members goes neither for publications nor for meetings, but for intangibles which, overall, may be of as much or more benefit to individual members, to the profession, and to the country, than the tangible benefits received. A separate article could well be written on this.

All of which leads up to the current question before AIME members, and on which most of them will soon be asked to vote: Shall the dues of Members and Associate Members be raised five dollars and of Junior Members two dollars for the years 1950, 1951, and 1952? A statement to the entire membership appears on the first page of the All-Institute section in this issue. Some felt that this statement should be as condensed as possible for quicker reading; others that full details of the operation of the Institute should be repeated, with answers to all the more frequently asked questions. The majority consulted favored the first view, but with the understanding that statements of both types be prepared, and that the more thorough discussion should go to Local Section Chairmen for use in conducting discussions at Local Section meetings and to have available for those interested.

Revolutionary changes are in progress with the Institute. Following the exhaustive study made by the Johnson Committee, whose report was published with the March, 1948, issue of *Mining and Metallurgy*, we believe the value of the Institute to its members has increased in many ways. Further, its opportunity for increased income from sources other than dues has, it is believed, been broadened greatly. More changes to benefit members are being made in the current year, and some, such as a field secretary for the Mining Branch, seem likely to be authorized just as soon as AIME finances permit.

The Section delegates at San Francisco, after discussing the matter for several hours, voted overwhelmingly for the proposed increase for the next three years—but only for the next three years. Conditions may be quite different in 1952. Unfortunately, only a small proportion of Institute members could be there. To those who were not, we ask that you, too, accept the decision made there to invest in the future of your Institute.

Whether our low-grade deposits can be mined to supplant diminishing high-grade reserves will be decided by progress in . . .

. . . Iron Ore Beneficiation

By FRANCIS X. TARTARON • MANAGER OF ORE RESEARCH, JONES & LAUGHLIN STEEL CORP., MEMBER, AIME

Beneficiation is the use of technological methods for the improvement of quality and structure of iron ores so as to render them usable in current smelting operations or to improve their usability. In considering the utilization of beneficiation on low-grade iron ores, it is first necessary to examine the need for such treatment. This need is directly related to the reserves of high-grade ore and the possibility of exhaustion of these reserves in the near future. Viewing the iron ore industry as a whole, exact knowledge as to the duration of high-grade reserves and the final technical and economic outcome of exhaustion of these reserves is impossible at the present time. The situation is a complex one involving discovery and location of new ore deposits, the separate activities of large industrial organizations, the national welfare, and finally, the general economic situation in the future. No one knows just what pattern will be finally formed by these factors. But, there is the steady pressure to produce 50 million or more tons of high-grade ore for furnace consumption. Currently about 100 million tons are being produced. If this quantity must be obtained by beneficiation eventually, considerable time is necessary to make adjustments in mining, to determine the most economical flowsheets, to operate pilot plants, and, last but not least, to obtain the necessary finances. Plants must be erected capable of treating 50,000 to 100,000 tons a day with tailing disposal equal to about two thirds of this amount. Quantity of ore mined must be tripled, as compared with present mining operations on the Mesabi Range. The transition is one of stupendous proportions and preparations must be made far in advance of actual need.

Latest figures reveal that the Mesabi Range yields about 65 per cent of the total ore production in the United States. The future of high-grade reserves on the Mesabi Range is necessarily a preponderant factor in the steel industry and in the need for beneficiation. Estimates of these reserves differ sharply but, for purposes of planning, the consensus is that twenty years' duration is a safe limit. The Mesabi Range also furnishes vast reserves of low-grade ore. The so-called "taconite" deposit is estimated to contain some 60 billion tons of crude from which 20 billion tons of high-grade may be derived. The iron mineral, however, is distributed in the ore in a fine particle size and to liberate this mineral prior to concentration, grinding through 100 mesh at least is required. Concentration of this fine material is by the relatively expensive flotation or reduction-magnetic separation process. Thus the utilization of the Mesabi low-grade ores involves a large increase in operating cost, placing them beyond the range of current ore prices. On the eastern end of the Range, however, there exists a deposit of magnetite ore stated to comprise some 5 billion tons from which approximately 1.7 billion tons of concentrate may eventually be obtained. The cheap magnetic concentration process can be employed on this ore. This, together with a sharp reduction in Minnesota taxes on taconite, has apparently brought the magnetic taconite ore within the realm of present economic conditions. At the present time, a proving plant, operated by the Pickands-Mather Co., is in operation at Aurora, Minn., treating 75 tons per hour of magnetic taconite. Grinding is through 100 mesh. Twenty-five tons per hour of concentrate are produced and pelletized by the Minnesota pelletization process.

Thus, by focusing on the Mesabi Range, we have a core of knowledge concerning the future of the iron ore industry. There are, roughly, twenty years to prepare for exhaustion of the high-grade ores. A vast quantity of low-grade ore exists which on beneficiation can produce the tonnage required for the furnaces. On the eastern end of the Range, a portion of this ore is of such nature that it may be treated under present economic conditions. Hence, the transition from high-grade to low-grade is already taking place.

Michigan's low-grade ore is also the taconite type, hematite being the predominant iron mineral. Reserves have recently been estimated to be about 2 billion tons from which some 725 million tons of concentrate may be derived.

The preceding considerations were devoted to the broad picture of iron

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ore production, the objective being the maintenance of flow of 50 million or more tons of ore to the furnaces. When, however, we turn to the problems of the individual industrial organizations, a much more urgent situation is revealed. It is not a matter of twenty years but of one or two years and methods of beneficiation employed must be clearly economic and immediately applicable. The problem in these cases is not the total exhaustion of reserves, but the maintenance of production schedules. As one deposit is exhausted, another must take its place. The type ore subjected to beneficiation in such cases is known as "intermediate-type" ore. The salient characteristic of such ore is that fine grinding is not required; concentration is performed on relatively coarse particle mixtures, hence, cheap treatments can be employed. In the Minnesota and Alabama ore fields, gravity concentration predominates, whereas in New York and Pennsylvania, magnetic separation methods are employed. Negligible concentration is practiced in Michigan at the present time.

In terms of average production of iron ore in the United States from 1942 to 1946 about 15 per cent represents beneficiated intermediate ore from the Lake Superior district, three per cent from the Northeastern district, and one per cent from the Southeastern district. Thus the bulk of the concentrate comes from Minnesota. Reserves of Minnesota crude intermediate-type ore are estimated at 300 million tons of producible concentrate, those of the Northeastern district at 500 million tons of crude. In the overall picture of the iron ore industry, the intermediate-type ores are not important due to relatively low reserves available. But, they are supplying current needs at current prices and at present are filling the gap between supply and demand.

nature of beneficiation processes

The raw materials of beneficiation are, in the main, the products of nature occurring at or near the surface of the earth. While there is considerable variation in chemical composition and physical form of these products, yet from the point of view of beneficiation they are treated in accordance with a few simple principles. A low-grade ore is an aggregate of different species or kinds of minerals, the minerals occurring in particle or grain form of varying size. In most cases, these mineral particles are consolidated in a rock which may be original or partly or completely decomposed. In other cases, they may be a simple mixture of free particles of the constituent minerals. Where the particles are consolidated so that there is attachment of particles of different kinds of minerals to one another, severance of liberation is required prior to concentration. This is ordinarily accomplished by crushing or grinding. The size range resulting from this crushing or grinding determines the concentration method as well as the economics of the treatment. For example, at the present time any iron ore requiring crushing and grinding through 325 mesh to effect liberation is questionable as to economic beneficiation under present conditions, regardless of the method of concentration employed.

Concentration is the separation of the particles of one mineral species from the others and this is effected substantially in all methods by means of differential motion. We are dealing with a mixture of particles of different mineral kinds and by imparting motion to one kind different from the others, separation is effected. This is the almost universal method employed in concentration—differential motion of particles of one species of mineral from those of another. This differential motion is usually accomplished by three broad methods: (1) gravity concentration, wherein particles of different specific gravities move differently in a resistant medium such as water or air; (2) magnetic separation, wherein magnetizable mineral particles take different paths in a magnetic field as compared with non-magnetizable mineral particles; and (3) flotation, wherein particles of one mineral kind are reagent coated so that they adhere to air bubbles, and the buoyancy of the bubble-mineral aggregate causes motion to the surface of the liquid whereas the nonadherent particles remain in suspension.

Subsequent to separation, we have agglomeration or reconsolidation of the usable mineral so as to prepare it for the smelting operation. The blast furnace cannot retain material less than approximately ¼-in. size, and where concentrates are too fine, it is necessary to join the particles into larger aggregates. In the size range of ¼ in. to 100 mesh this is accomplished by sintering whereby a moistened mixture of coal and ore is burned by means of air being sucked through the heated mass. Consolidation takes place, forming chunks. Where the ore is preponderantly below 100 mesh in size, the porosity of the bed is too low to permit adequate passage of air. A different method is now being tested on a plant scale. This is the so-called Minnesota pelletization method, whereby moistened concentrate containing fifty per cent or more of minus 325 mesh fraction is rolled into balls by means of a rotating cylinder. These balls are then baked in a shaft furnace which causes hardening and resistance to impact and abrasion. The method is rated as cheaper than sintering and production runs are in progress at Aurora, Minn.

gravity concentration processes

Gravity processes are utilized in Minnesota and Alabama and to a small extent in the Northeastern district. In such processes, the phenomenon that is utilized is that minerals of higher specific gravity settle faster in water than those of lower specific gravity. Various mechanical devices are employed that fit best the characteristics of the ore to be treated. The most important of these characteristics are (1) magnitude of difference in specific gravity of the minerals, (2) size range present after liberation, and (3) shape of the particles.

In a vacuum, all mineral particles regardless of specific gravity, size or shape, move toward the earth with equal acceleration, and if started at the same instant, with equal velocity. Hence, no separation is possible. When, however, such particles are immersed in a resistant medium such as water, differences in settling velocity are distinct. Mineral particles of higher specific gravity settle faster than those of lower specific gravity. This effect, therefore, must be produced by the medium. In a vacuum,

the only force operating is the force of gravity, but in a resistant medium, two new forces are introduced, buoyancy and friction. If this situation is analyzed in detail, it will be found that buoyancy is the force responsible for the difference in settling rates between particles of different specific gravities. Furthermore, this unequal settling takes place without regard to size or shape of particle. It is based solely on difference of specific gravity.

Friction, on the other hand, is a force that interferes with the effect produced by buoyancy. It acts against the differential derived from this force. Size and shape of particle are intimately linked to the force of friction and it is because of this that gravity concentration is inefficient and complex. As a result of friction, fine particles of high specific gravity settle equally with coarser particles of lower specific gravity and separation cannot be made. This is known as size interference. In one case this effect of friction is helpful. Where the ore impurity consists preponderantly of fine low-specific gravity mineral, such mineral is slowest settling and easily sepated. In Minnesota, over eighty per cent of the beneficiation is done by simple water washing of the ore so as to remove fine silica and produce marketable concentrate.

The force of buoyancy can be magnified by raising the specific gravity of the medium. This can be done by increasing the proportion of ore solids to water or by adding a separate mineral of very high specific gravity to the ore pulp.

We have then, two situations in gravity concentration: (1) when a mechanical arrangement is so contrived that buoyancy is a predominant factor, then sharpest separations take place and there is negligible size interference; (2) when buoyancy is less predominant, friction causes size interference as well as slowing up of the differential motion as a whole. Separation is much more difficult. In general, friction can be minimized and buoyancy utilized in the coarsest fractions of the feed. It is in the finer portions of the ore that friction predominates and causes interference. To eliminate this interference, it is necessary to divide the feed into narrow size bands within which fine material of higher specific gravity settles faster than the coarser gangue minerals. The finer the ore, the slower the over-all settling rate and the longer the time required to obtain separation. Hence, on finer ores, the capacity of machines decreases and the size and quantity of machines is larger to treat a required tonnage.

In practice, we find that buoyancy is applied on a size range of 1¼ to 3/16 in. This is utilized in the so-called heavy-density process which will be described later. Below 3/16 in., friction enters as so important a factor that only imperfect application of buoyancy is possible. Methods devised to treat the minus 3/16 in. range are full of complications. No single machine can treat the full range; most give only a partial answer. Some give a good answer but are difficult to use. For example, we are finding that the shaking table can concentrate ore from 3/16 in. to 20 mesh and from 20 mesh to 150 mesh when treated separately. Yet this machine is of such small capacity and requires so much floor space to treat a high tonnage, that its application is problematical. The hydrosizer makes a partial concentration on minus 10-mesh feed. The Humphreys spirals handle ore from 10 or 20 mesh to 150 mesh. A new machine claims to concentrate from 3/16 in. to 65 mesh. Another is being tested on 65 to 325 mesh. Below 325 mesh no one has or expects an answer by means of gravity concentration.

The reason for utilizing gravity concentration is that it is cheap. Magnetic separation would be far superior if the iron mineral were magnetite. But with hematite, the only economic method is by gravity processes. Flotation cannot be employed on material coarser than 65 mesh and even on the minus 65-mesh material it is still too expensive.

washing

In Minnesota, there are two types of intermediate ores, one known as wash ore, the other as "jig" ore. In wash ore, the silica particles are much finer in size than the iron mineral particles, hence, a sizing operation can effect concentration. This is simply and cheaply done by suspending the ore in water in a container allowing the coarse material to settle and overflowing the fines. The machines employed are log washers and mechanical classifiers.

Over eighty per cent of Minnesota shipments of beneficiated ore represent wash ore. The remainder is known as "jig" ore, and contains silica particles of the same size range as iron mineral particles. Hence, more elaborate concentration methods are necessary. The name "jig" ore was derived from the machine that originally was employed to treat such ores. The jig is now almost obsolete on the Mesabi Range, having been replaced by the heavy-density process.

heavy-density process

The heavy-density process utilizes the phenomenon that when finely ground mineral of high specific gravity is suspended homogeneously in water, a new liquid medium is formed having a higher specific gravity, higher viscosity, and higher resistance to movement of particles. By varying the proportion of suspended particles to the water, the specific gravity can be raised or lowered. When minerals of different specific gravities are introduced into this medium, the lighter can be made to float and the heavier to sink. However, as the introduced minerals are decreased in size, more and more interference with the separation takes place due to the high resistance to motion and an increase in viscosity brought on by the presence of the fine minerals to be separated. As a result, in plant operations the lower size limit is around 4 mesh or 3/16 in. The upper size limit on iron ores is 1½ in. Within this size range, a highly successful separation is obtained, and the use of heavy density is rapidly expanding on the Mesabi Range.

The material suspended in water is ferrosilicon, having a specific gravity close to 7 and ground through 65 to 100 mesh. Sometimes, magnetite is employed in conjunction with ferrosilicon where low specific gravities are desired. Specific gravity of the liquid medium varies from 2.6 to 3.2.

Apparatus employed consists of two units: the separatory unit and the medium purification unit. The sepa-

ratory unit consists of screens to size the feed, a cone or a mechanical classifier into which sized ore and medium are introduced, followed by screens to separate the medium from the concentrate and tailing. This medium goes to the purification unit which consists of magnetic separators and dewatering machines. The so-called "densified" medium is then reintroduced into the circuit.

As an example of heavy density separation, the test results in the accompanying table were obtained on a Minnesota ore in our laboratory. It is expected that the same results can be obtained in plant operation.

Results of Heavy-Density Separation Tests on a Minnesota Ore

Specific Gravity of Medium	Percent Weight of Feed	Concentrate, Percent Iron	Concentrate, Percent Silica	Concentrate, Percent Iron Recovery
2.70	90.0	58.48	12.02	96.28
2.85	79.5	59.56	10.14	87.01
3.00	69.4	60.72	8.54	77.02

It can be seen from these results that by adjustment of the specific gravity of the medium, concentrates of different grades can be obtained with corresponding changes in recovery.

magnetic separation

Magnetic separation is employed preponderantly in the northeastern section of the United States including New York, New Jersey, and Pennsylvania. It is based on the phenomenon that the iron mineral magnetite is easily magnetizable, hence, when particles of magnetite are passed through a magnetic field, they take a different path from particles which are nonmagnetizable. The explanation of magnetization is that the molecules or atoms of substances are unit magnets. In magnetizable materials, the molecules can rotate easily, hence, when placed in a magnetic field, north and south poles line up in the same direction. The over-all magnetic field is then the sum of the unit magnetic fields. In nonmagnetizable substances, the molecules cannot rotate, the unit magnets neutralize one another and the over-all field remains at zero or low magnetic intensity. When a substance is magnetized, the space surrounding it becomes energized or activated, and when brought into contact with a similarly activated space, reactions occur which are reflected in the motions of the material bodies to which these activated spaces are linked. Thus, a magnetized bar of steel can be suspended in mid air with no material support. Below this piece of steel is another bar of steel, also magnetized. The space between them is energized and keeps the upper bar suspended in mid air.

Magnetic separation is the cheapest and most efficient of all beneficiation processes. There is no size interference as in gravity concentration except where the feed is composed predominantly of slimes. Here, there is the lumping of the fines with most of the impurities trapped in the lumps. But, most ores do not contain such a predominance of slimes and no serious problem is present. The greatest difficulty with magnetic separation is that the major tonnage of iron ore reserves contains the nonmagnetizable hematite rather than magnetizable magnetite. Thus, the process has limited application. Hematite can be reduced to magnetite by heating and using reducing agents such as carbon monoxide or hydrogen, but the cost of this method is high at the present time. Efforts are constantly being made to reduce this cost to within economic limits.

In the practice of magnetic separation on a high tonnage basis, it has been found that the magnetic field cannot be adjusted so as to make a sharp distinction between free iron mineral and iron mineral attached to gangue. A particle of quartz with ten per cent of its weight as attached magnetite will go into the concentrate together with free iron mineral. Thus, segregation of attached mineral particles into a separate middling product, which is common in other processes, does not take place in the magnetic process. However, advantage is taken of this factor to reduce crushing and grinding cost. The ore is crushed to produce free gangue mineral, considerable locked mineral, and some free iron mineral. It is then subjected to magnetic separation which segregates the free gangue mineral only, which is rejected. The reduced quantity of concentrates is then crushed finer and the process repeated. By this means, less and less quantity of material is subjected to crushing and grinding to the point where complete liberation takes place and final grade of concentrate is attained. The standard flowsheet for magnetic separation is stepwise liberation and concentration based on the characteristic behavior of the magnetic field.

On the eastern end of the Mesabi Range, there is a deposit of magnetite ore running about 25 per cent iron, estimated to contain about 5 billion tons from which 1.7 billion tons of concentrate may be derived. This deposit originally contained hematite, but an intrusion of igneous rock reduced the hematite to magnetite and at the same time consolidated the ore into an extremely hard rock. Drilling for mining operations is expensive and for a long time this deposit was uneconomic to treat. Changes produced by the war and a lowering of state taxes has apparently made it possible to exploit the deposit. Pickands-Mather Co. is now operating a 75-ton-per-hour pilot plant producing high-grade pellets as final product for blast furnace use. If successful, full scale plants will be erected.

Machines currently employed for magnetic separation are of the belt type and the drum type. The belt-type machine has an endless belt, the lower branch of which runs through ore pulp flowing through a compartmented box. Above this portion of the belt is an electromagnet with the north and south poles alternating. As the belt passes beneath the magnet and through the pulp, magnetite adheres to the belt until it passes beyond the magnets. It then drops into the concentrate compartment of the box. Alternating north and south magnets cause rotation of the magnetic particles so as to free trapped gangue.

The drum-type machine has rotating cylindrical drums immersed part way in the pulp with stationary magnets inside the drums. The pulp also flows through a box usually containing three compartments, each with its individual drum, the three drums operating in series. Concentrate from the first drum is retreated by the second, and the second concentrate by the third drum. The drum-type machine appears to be superior to the belt type on fine material and is being used on the magnetic-taconite at Aurora, Minn.

flotation process

Flotation has not yet found application in iron ore concentration due to the fact that it is a relatively expensive process and requires a large investment in plant. However, if taconites are to be beneficiated, flotation will loom as an important method of the future. Hence, it is reviewed here.

In flotation, a suspension in water of ore particles 35 mesh and finer is agitated in a cell through which air bubbles are rising. By adding the proper chemicals to the pulp, mineral particles of one type adhere to the air bubbles and rise to the surface, forming a froth which is skimmed. Thus, one mineral is removed and the other or others remain in the pulp, flowing through a series of cells to the discharge end of the machine.

The adherence of mineral particles to air bubbles is effected by the use of a special type of organic compound having a characteristic chemical composition and physical properties. Molecules of such compounds consist of two primary ingredients. One is a hydrocarbon portion characterized by water repellency and water insolubility as well as chemical inertness. The other is a water-soluble, water-attracted, chemically-active group attached to the hydrocarbon portion. Oleic acid is an example of a common type flotation collector. This compound contains a straight chain hydrocarbon group of seventeen carbon atoms and to it is attached a carboxyl group. At an interface between water and air, such molecules become oriented with the hydrocarbon projecting into the air and the carboxyl remaining in the water. When oleic acid is dissolved in water (it is slightly soluble), the surface of the water can be shown to have the properties of an oil rather than of water. The hydrocarbon portions of the oleic acid molecules concentrate in the surface layer and thus cause the change in properties.

When particles of an ore pulp and flotation collector are mixed together in water, the collector reacts selectively with the mineral particles of one kind and the effect of this reaction is to cause adherence of collector to mineral. Adherence and selectivity are based on chemical phenomena and the whole field of chemistry is available for utilization in devising separations of minerals from one another.

Once a flotation collector has been properly attached to a mineral particle, adherence to air bubbles follows automatically. On contact of bubble and coated mineral particle, the force of water repellency is brought into play and acts to resist separation because separation means re-entry of the hydrocarbon into the water phase.

Frequently a mineral does not react with a collector or if it does, it is desired to suppress this reaction. By the use of auxiliary reagents, it is possible to alter the chemical nature of mineral surfaces so that reactions different from normal are obtained. Thus, iron minerals react with oleic acid-type collectors and normally are floated. By the addition of soluble starch, the iron mineral becomes coated with this material and its reaction with oleic acid prevented. Addition of lime causes alteration of quartz surface so that a reaction takes place with the collector. Quartz now is coated with collector and it adheres to air bubbles. In this way new separations are devised and methods of separation can be developed on any combination of minerals.

Flotation revolutionized the nonferrous metal mining industries because substantially all ores that were liberated at sizes adequate for gravity concentration were depleted years ago. Ores now treated resemble the taconite ores and flotation is the only method applicable. However, on iron ores, the possibility of reducing hematite to magnetite must be considered and it remains to be seen which method will eventually be adopted.

Flotation, when compared with gravity concentration and magnetic separation, is a relatively expensive process. The existence of ore reserves that can be concentrated by these two methods keeps flotation in the background. In the course of time, however, as the high-grade and intermediate ores become more and more difficult to obtain, flotation will emerge as an important method and may become the predominant process.

future of iron ore beneficiation

As indicated in the opening paragraphs, the maintenance of a flow of 50 million or more tons of high-grade ore to the furnaces will involve a stupendous transformation in the iron mining industry when such ore must be obtained by beneficiation. The magnitude of beneficiation operations will increase accordingly. The production of 50 million tons or more a year of high-grade concentrate means the mining and treatment of about half a million tons of crude per 24 hour day. Mining must be performed in hard rock as contrasted with the loose material now being dug. Crushing and grinding must be done so as to reduce boulders 4 to 6 ft. in size down to 100 mesh or finer. Beneficiation must be followed by pelletization. Large scale plants will be necessitated to gain greatest economy and minimize the inevitable increase in cost.

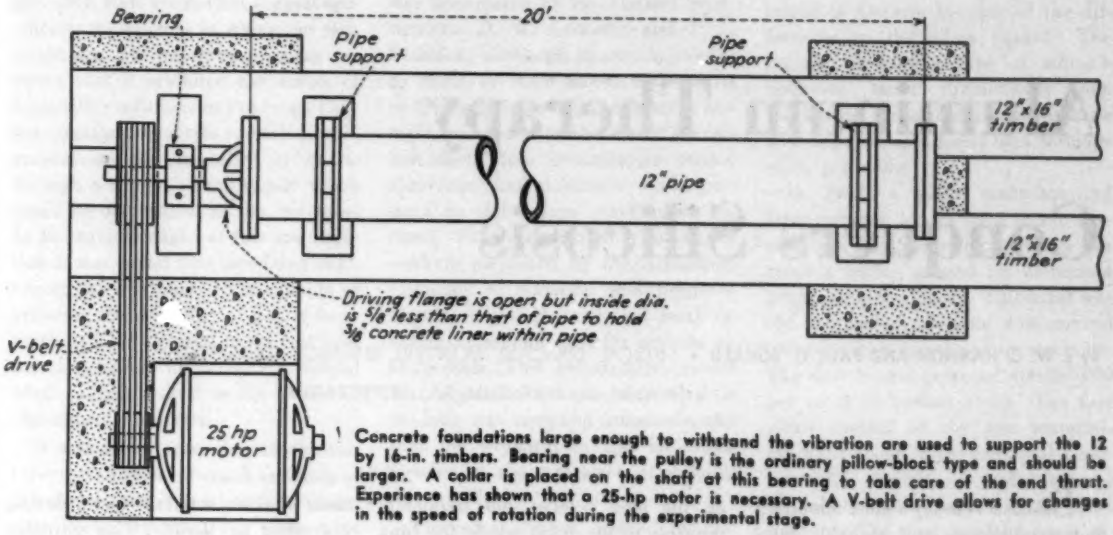
Plant investment to treat taconite-type ores has been estimated at $10 to $20 per ton of concentrate. At 50 million tons annual rate of production, this means ½ to 1 billion dollars. This money involves no generation of compensating profit, but is an expense to maintain ore production and a charge against future profits of the industry.

The question naturally arises as to how this transformation from high-grade to low-grade ore will take place. How will such a complex and unpredictable situation finally be resolved? The answer is given by the individual exploratory projects now in operation or those which are definitely on the planning board. Mention has been made of the Pickands-Mather proving plant. In addition, the Reserve Mining Co., a subsidiary of Oglebay Norton & Co., has taken initial steps leading to the construction of a magnetic taconite concentration plant at Beaver Bay, Minn. Final output is expected to be 10 million tons a year. This same company has started operation of a pelletizing pilot plant at Ashland, Ky., to prove the practicability of agglomerating taconite concentrate. Another company reports that flotation can be successfully applied to a lean specular hematite ore from the Republic formation in Michigan.

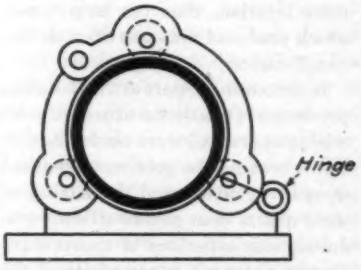
It is these pioneering projects that are paving the way toward the final answer. As experience is accumulated and success achieved, the magnitude and scope of operations can be increased.

Centrifugal Lining of Pipe

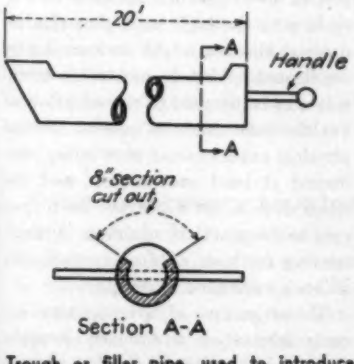
By R. C. MAHON • SUPERINTENDENT, HANNA IRON ORE CO.; MEMBER, AIME



Concrete foundations large enough to withstand the vibration are used to support the 12 by 16-in. timbers. Bearing near the pulley is the ordinary pillow-block type and should be larger. A collar is placed on the shaft at this bearing to take care of the end thrust. Experience has shown that a 25-hp motor is necessary. A V-belt drive allows for changes in the speed of rotation during the experimental stage.



The two bearings on the pipe, made at the mine, consist of small rollers evenly spaced in a steel frame which can be opened to admit the pipe.



Trough or filler pipe, used to introduce the sand and cement into the pipe, has small legs welded to it so that it does not remove any aggregate when withdrawn.

Operators concerned with the destruction of their piping by acid mine waters will be interested in the method by which this problem was solved at the Cardiff mine of the Homer group.

Rubber lined, or acid resisting metal pipes were found too expensive. Casting concrete lining in pipe would have required a minimum thickness of one inch, thus excessively reducing the pipe's diameter, as well as taking twenty four hours per length of pipe. The Naylor Pipe Co. of Chicago, having experimented with centrifugal lining of pipe with concrete, provided information which eventually solved the problem.

An experimental plant was constructed as shown, and the following procedure developed:

(1) Kerosene is used to remove the interior oil coating of new pipe. Closed with blank flanges, the pipe is revolved for eight minutes at varying speeds. Stopping and starting the motor achieves a good washing action. The kerosene is then drained off, and similar washing action with caustic soda removes any excess. Swabbing is done with burlap fastened to a ½-in. pipe.

(2) The aggregate, made of one part quick-setting cement and two parts sand, must be carefully screened, thoroughly mixed. It is placed evenly in a 6-in. filler trough, which is inserted in the pipe, inverted, then withdrawn. The concrete retaining collars bolted on the pipe have an opening 1/16 in. less in diameter than the desired thickness of concrete, to allow the water to drain. Slow turning of the pipe further mixes the aggregate and permits even distribution. The speed is increased to 1000 rpm, maintained for six minutes. A two minute stoppage then permits the water to drain off, and is followed by two more minutes of revolution to attain a smooth finish. The pipe is removed, and a wet burlap bag placed over each end to ensure the slow curing of the concrete and prevention of cracks.

This process is working satisfactorily, and can be recommended as a cheap, efficient method of constructing acid-proof discharge lines.

Materials required per cu. ft. for various pipe sizes and lining thicknesses.

Pipe Diameter (in.)	Cement (lb.)	Sand (lb.)	Lining Thickness (in.)
8	2.3	4.6	¼
10	5	10	⅜
12	5.5	11	⅜

Aluminum Therapy Conquers Silicosis

By J. W. G. HANNON AND PAUL G. BOVARD • MEDICAL DIRECTOR, McINTYRE RESEARCH FOUNDATION, AND M. D., TARENTUM, PA., RESPECTIVELY

Silicosis is today's most important industrial disease and probably dates back to the Stone Age. Since the industrial revolution, increasing attention has been paid to those occupations where mineral dust is present in the air breathed by the workers. For many years it was assumed that the inhalation of all mineral dusts was hazardous, but investigations conducted in several countries pointed the statistical finger of guilt at free silica in any of its numerous physical forms as a dust of outstanding toxicity. Recognition of silica as the chief hazard has resulted in widespread use of the term "silicosis."

Depending upon the concentration of finely divided silica dust to which the individual is exposed and the duration of exposure, silicosis may become a disabling condition in from one to thirty years. The structure of the lung and respiratory passages is such that only minute particles of silica can gain entry to the air cells in the lung (5 microns or under are most toxic). When these minute particles gain entry to the lung tissues they stimulate certain protective cells in the lung to multiply at an excessive rate. The cells undergo inflammatory changes which result in nodular scars and a low-grade inflammation of the lung tissue. These progressive changes in the lung structure gradually encroach on the lung reserve and frequently progress to the point where the lung is unable to oxygenate enough blood to carry on the requirements of the bodily functions. The symptoms of pulmonary disability produced by silicosis are: shortness of breath which is most marked on exertion, cough, distress, and a sensation of tightness in the chest.

new concepts disclosed

For many years it was assumed that the hard, sharp particles of silica in the constantly moving lung damaged the lung tissues directly as the result of their physical presence. This explanation seemed a reasonable one, but doubt was cast on its correctness when investigators found that exposure to diamond and carborundum dust, the particles of which were both harder and sharper than those of silica, did not produce disabling damage to the lung. Further experiments gave rise to a new theory that the silica particles did not damage the lung due to their physical presence but dissolved in the lung fluids, producing toxic solutions which in turn caused the abnormal lung changes. This theory is referred to as the chemical theory. Tests wherein silica particles of various sizes, ranging from one to twelve microns, were injected into animals, showed that only certain concentrations of silica solutions had a damaging effect on tissue. Tiny particles, one to three microns in size, proved more injurious than the larger ones, which produced the same effect as diamond, carbon, or coal particles.

In the northern part of the Canadian province of Ontario the extensive gold-mining operations were producing silicotics because the gold was deposited in veins of quartz and the mining of these quartz veins caused silicosis-producing concentrations of quartz dust. Sixteen years ago a committee of the Ontario Mining Association, a group from the McIntyre Porcupine mine, and The Department of Medical Research, Banting Institute, University of Toronto, started a co-operative effort to investigate the problem of silicosis with the high hope that this industrial disease might be completely eradicated. Already particular attention was being paid to the selection of healthy individuals as miners, routine physical examinations were being conducted at least once a year, and the silica dust in the mines had been lowered to the practical minimum by engineering methods of dust control, but silicosis continued to develop.

These groups of investigators became interested in a theory brought forward by the famous English physiologist, the late J. S. Haldane. Mr. Haldane believed in the existence of

an antidotal rock, which on being inhaled and deposited in the lungs together with silica dust, in some way neutralized or counteracted the usual effects and so prevented the silica dust from producing its characteristic damage. Mr. Haldane did not suggest specifically the manner in which the rock might act, but an Ontario group believed that it inhibited the action of toxic silica solutions in the lung. They investigated the effects of various substances on the solubility of quartz through a simple solubility test which could be determined in the test tube. In the earlier stages of this investigation it was found that powdered coal, carbon, or iron oxide were capable of reducing the solubility of quartz to as much as forty per cent in the test tube but they had no appreciable antidotal effect on quartz dust in the tissues of experimental animals.

It was found later that in the test tube the addition of small amounts of aluminum powder to silica dust almost completely prevented the solution of silicic acid. This finding was so promising that extensive animal experiments were undertaken. These showed that inhalation and deposition of a small amount of aluminum powder in the lung, when intimately mixed with silica dust deposited there, would prevent the development of silicosis. This occurred by the formation in the lung tissue of positively charged hydrated alumina which became adsorbed to the surfaces of the negatively charged quartz particles. This coating prevented the silica from dissolving in the lung to produce toxic concentrations of silica solution. Further experimentation showed that the exposure of silicotic animals to aluminum powder was beneficial in that it prevented the usual inexorable progress of silicosis. Insolubilization of the quartz permitted the lung to gradually rid itself of silica and its tissue to return to normal structure.

from laboratory to mine

The workers who found the antidotal effects of aluminum believed that its main importance would be in the prevention of silicosis but they knew that the proof of its prophylactic properties might take ten or fifteen years. It was therefore suggested that aluminum powder be tried in the treatment of disabled silicotic miners, since reasonable evidence of its ability to check the progress of silicosis and minimize the degree of pulmonary dysfunction could be obtained within three or four years. Accordingly, an investigation was undertaken by two clinical investigators. D. W. Crombie and J. L. Blaisdell. Although aluminum powder by itself, or when mixed with quartz in the lung tissue of experimental animals, was found to be as inert as carbon dust, these investigators needed assurance that aluminum would produce no deleterious reaction in humans. They investigated a number of workers employed by the Aluminum Company of America who prepared aluminum powder and had been inhaling aluminum dust for periods up to 23 years. This investigation showed that aluminum powder deposited in the lung was inert and innocuous, and that the proposal to use aluminum powder in the treatment of silicosis was justifiable.

Thirty-five miners, judged by Ontario's Workmen's Compensation Board to be silicotics with dysfunction, were selected for clinical trial, and given inhalations of aluminum powder. At first the daily inhalations lasted for two minutes, but these were gradually increased to an exposure of thirty minutes. Nine silicotic miners were kept as controls and were not given aluminum treatment, but miners of both the treated group and the control group continued with their usual work. At intervals of three months, pulmonary function tests were carried out on the members of both groups.

In the April, 1944, issue of the *Canadian Medical Association Journal*, Mr. Crombie and Mr. Blaisdell reported the results of aluminum treatment carried out over a period of three and one half years. Their conclusions were that in the control group, 65 per cent of the men showed increased silicosis while the remainder were unchanged; while in the aluminum-treated group, 65 per cent of the men were improved and the remainder were unchanged. These results showed that aluminum treatment of these silicotics with pulmonary dysfunction resulted in diminution of the dysfunction in a high percentage of cases, and the usual progress of the disease was prevented.

seven year test conducted

While the clinical trial of aluminum therapy was under way in Ontario, a similar trial was carried out by one of us (Hannon), and the results were even more favorable than those obtained in Ontario because of the differences in the silica hazard. The rapidly developing type of silicosis responds more dramatically and quickly to aluminum treatment than does the type of silicosis that develops more gradually.

In 1942, a plant manufacturing large ceramic blocks used in the construction of glass melting furnaces was made a testing ground for aluminum prophylaxis in silicosis. This plant was old and defied adequate dust control without rebuilding the entire structure. The dust counts averaged 100,000,000 per cu ft in certain areas. The free silica content of the raw materials averaged about 75 per cent, and a considerable amount of tridymite and crystobolite was present in the fired product. The dust particles were extremely small, many ranging from five microns to less than one micron. The production practices producing the greater amount of dust were material handling, ball milling, and dry pan grinding, and chipping and sawing the fired product. There had been no basic changes in dust control in the above operations for ten years. It was considered a desirable experimental environment.

The incidence of silicosis in this plant was high. It was not unusual for a workman to develop X-ray evidence of nodular silicosis in a relatively short period of time. The majority of the men engaged in chipping fired tank blocks developed X-ray evidence of silicosis in three to four years. After extensive exposure, the X-ray picture frequently revealed massive lesions in the upper lobes of the lungs that resembled tuberculosis. However, autopsy failed to show infection in most cases although decreased pulmonary reserve in these men was sufficient to produce disability of varying degrees of severity.

Thirty-five workmen employed in 1942 were selected for a study of the value of aluminum as a prophylactic measure against silicosis. All of these men were exposed to practically the same silica hazard in regard to par-

ticle size and concentration of dust. Eighteen men, by mutual agreement, received inhalations of aluminum powder and seventeen men were not treated and used as controls. Seven of the men in the treated group and six men in the control group had exposure to silica prior to 1942. However, their exposures were comparable.

The aluminum powder was administered periodically thirty times per year. Each treatment consisted of a ten minute inhalation of aluminum powder given weekly for thirty weeks, followed by a rest period of twenty-two weeks with no treatment. Occasional slight deviation from this routine was allowed in several individual cases for reasons peculiar to the particular workman under treatment. The majority of the treated group experienced no untoward reaction associated with the inhalations. Occasionally some cough was experienced shortly after treatment, but was relieved by a drink of water.

success attained

The eighteen men treated in this manner over a seven year period were periodically examined. Routine chest X-ray examinations were made at intervals over the entire period. After this exposure of seven years to high concentrations of silica dust these men have no symptoms or physical signs of silicosis. They show no disability and the X-ray films of the chest show no significant changes from the normal lung picture present seven years ago.

Of the seventeen men in the control group, two have developed total disability due to silicosis; a few have mild symptoms but stay on the job. The remainder have no symptoms and no complications.

Results of Aluminum Therapy Test, 1942 to Present

	Treated Group	Control Group
Number tested	18	17
Beginning silicosis	0	10
Undetermined	0	2
Normal chest	18	5

The chest films of ten in this control group showed changes characteristic of silicosis not present in 1942. In two cases there was increased density of lung markings which was not sufficiently characteristic to be definitely classified as silicosis. In the five remaining chest films no significant abnormal changes could be noted as having developed since the pre-employment examinations.

Drilling With Kilocycles

That overrated bugaboo known as "impossibility" was dealt another solid blow by men of science recently. The scene was a salt mine in Louisiana, where twenty-three assorted leaders of the oil industry, the Navy, and the Air Force gathered, sans fanfare, to view some electronic witchery which may alter the face of modern prospecting, and also aid America's defense against "the bomb."

The scientists went through 1800 ft of abandoned workings at the cavernous bottom of the Morton Salt Company's mine shaft in Grand Saline, Texas, cutting power lines and cables behind them, to attend the first public demonstration of deep transmission of radio waves into the earth. The strong signals they heard traveled through 700 ft of sedimentaries, 25 ft of cap rock carrying five to nine ft of salt brine, 400 ft of salt and 100 ft of air. The "impossible" had been accomplished.

Responsible for the new development is William M. Barret, who heads his own firm of consulting geophysicists in Shreveport. He spent fifteen years working to defy twenty-six formal papers and a handful of textbooks which said it couldn't be done, and then went on to use his system on a commercial basis, locating minerals in the South and West, before the public demonstration.

Barret's new system, which overcomes the reflection of waves at the earth's surface and also compensates for the attenuation of waves in the earth, is capable of plumbing far greater depths than the achieved 1200 ft, he says. But the geophysicists and military men see the transmitting and receiving device as a possible boon to prospectors, and of importance to national security should our industries move underground in the event of an atomic war.

All Geologists Invited

The Field Conference of Pennsylvania Geologists will hold its annual meeting May 27-29 at Lancaster, Pa. The Department of Geology of Franklin and Marshall College will be host. A major feature this year will be a trip through Southern Lancaster County to study the Martic overthrust problems under the leadership of Professor Ernst Cloos, of the Johns Hopkins University. Other field excursions will include the old Wood chrome mine, Gap nickel mine, other old metal mines, and the flood plain of the Susquehanna River.

For further details, address Dr. Richard M. Foose, Department of Geology, Franklin and Marshall College, Lancaster, Pa.

W. M. Barret, seated at left, and assembled witnesses, awaiting the radio signal which pierced 1200 feet of rock to reach them in the mine.

Omaha Public Library
Reference Dept.

Graduate Study Restricted to Few Schools

By J. D. FORRESTER • CHAIRMAN, DEPARTMENT OF MINING ENGINEERING, MISSOURI SCHOOL OF MINES AND METALLURGY, ROLLA, MO.; MEMBER, AIME

Many have been prone to credit the decline of professional interest in some branches of mineral industry education to the industrialists and other agencies who use our graduates. We hear the cry that industrial salaries are too low, opportunities for advancement do not exist, and the mineral industry specifically and generally is not interested in the engineer's efforts. Perhaps the time now has come when we should "dress-ranks," examine our practices, and publicize and encourage advanced technical training instead of laying all our troubles elsewhere. There can be no doubt but that industry is interested and stands ready and willing to co-operate. This is demonstrated by the numerous grants-in-aid and co-operative industrial projects which have been made available to those relatively few schools which have been encouraging graduate study and research. There is no dearth of research problems in any of the mineral industry fields and the sooner we realize the great opportunities for constructive, technical research in all areas of our profession the sooner we will reap the benefits of our engineering enterprises by closer liaison and broader understanding with industry.

An analysis is offered here of the status of graduate work and research in various phases of mineral industry education in the United States. It is based on a questionnaire sent to 56 schools of which 51 were returned.

The purpose of the study has been broadly of a two-fold nature: (1) to ascertain the character and degree of graduate study and research in various areas of mineral industry education in the United States, and; (2) to make interpretations of data as possible

(*Continued on p. 29 in back of magazine*)

Results of Survey Showing Financial Aid

Number of schools with industrial grants-in-aid	26
Enrollment (graduate) in such schools	638
*Percentage of above enrollment assisted by grants-in-aid	18.3
*Percentage of all enrollment (graduate) assisted by grants-in-aid	15.4
Number of schools with full-time instructors doing graduate work	17
Enrollment (graduate) in such schools	620
*Percentage of above enrollment acting as full-time instructors	13.1
*Percentage of all enrollment (graduate) serving as full-time instructors	10.7
Number of schools with part-time instructors doing graduate work	28
Enrollment (graduate) in such schools	644
*Percentage of above enrollment acting as part-time instructors	14.4
*Percentage of all enrollment serving as part-time instructors	12.3
Number of schools with nonteaching fellowships (or scholarships)	24
Enrollment (graduate) in such schools	743
*Percentage of above enrollment acting as fellows or scholars	18.6
*Percentage of all enrollment acting as fellows or scholars	18.3

* The precentages of enrollment have been factored and distributed by taking quantities reported for each institution and determining such relations as they apply in the whole.

Number of schools with co-operative, industrial, graduate-research projects	25
Number of projects	233

Results of Survey on Graduate Study from 51 Schools

	Schools Offering Postgraduate Work		Schools Now Giving Postgraduate Work		Number of Students Now Enrolled for Postgraduate Work		
	M.S.	PhD.	M.S.	PhD.	M.S.	PhD.	TOTAL
Mining Engineering	21	10	13	6	61	9	70
Mineral Dressing	16	9	9	4	32	15	47
Metallurgical Engineering	27	16	25	12	157	115	272
Mining and/or Engineering Geology	23	16	18	7	63	27	90
Petroleum Production Engineering	13	10	12	5	70	6	76
Petroleum Refining Engineering	10	4	7	3	52	7	59
Ceramic Engineering	15	7	12	5	73	31	104
Mineral Economics	3	2	1	0	1	0	1
Geophysical Exploration	8	8	7	6	29	7	36
				Total	538	217	755

Open-Pit Forum

Introducing a new department which is intended to disseminate the latest operating practices in open-pit mining. We hope that our readers will contribute information on their operations or discussion of the subjects presented.

Drilling and Blasting 12-in. Blastholes at Chino

By G. J. BALLMER • SUPERINTENDENT, CHINO MINES DIV., KENNECOTT COPPER CORP., SANTA RITA, N. MEX.; MEMBER, AIME

Drilling and blasting 12-in. blastholes started about the middle of 1946 and has worked out so well that about one half of the blasting, formerly done with 9-in. holes, is now done with 12-in. holes. In most of this work the harder benches were chosen for the 12-in. size because these were the areas where the greatest difficulty was encountered in thorough fragmentation.

At the start of this experimental work a 42-T Bucyrus-Erie churn drill was available whereas all other blasthole drilling was being done with 29-T rigs. The large drill was first equipped with a standard 9-in. string of tools but it could not drill quite as fast as the 29-T drills. However, when the weight of the string was increased about 700 lb, or to a total weight of about 3500 lb, it was found that the 42-T exceeded the drilling speed of the 29-T by about 25 per cent. When a 12-in. bit was substituted for the 9-in. bit the 42-T rig again dropped behind the drilling rate of the 29-T rigs. At this stage of the experiment the 42-T was using a 12-in. bit with detachable points and the total weight of the string of tools was about 3800 lb. It took longer to change the drill points than it did the regulation bit and this accounted for some of the slower drilling rate. When a heavier stem and standard construction 12-in. bits were used it was found that the 42-T could drill a 12-in. hole slightly faster than a 29-T could drill a 9-in. hole even in the hardest rock in the pit.

Shortly after the 42-T rig was all set to do regular blasthole drilling it was sent to another part of the property to drill water wells and it has not returned to the pit since. Consequently several 29-T rigs were equipped with strings of tools weighing approximately 3800 lb and at the present time six of these machines are drilling 12-in. holes. The progress is not quite as rapid as when these same rigs are drilling 9-in. holes. Some additional reinforcement was needed, but to date they are still performing in a satisfactory manner. Some of these rigs have been using 12-in. tools for eighteen months. The drilling rates are about as follows: 9-in. rigs, 10.5 ft per hr drilling; 12-in. rigs, 8 ft per hr drilling.

When it is further understood that the 12-in. rigs are, without exception, used in the hardest ground, this difference is not considered too great.

Hole spacing is different for a 9-in. shot than a 12-in. For instance, in a shot drilled with 12-in. tools the toe burden is increased at least three feet and the hole spacing approximately eight feet over a 9-in. shot in the same ground. No attempt has been made to decrease the amount of powder used per ton of burden and the saving lies entirely in decreased drilling expense and expense of loading holes. The results of blasting 12-in. holes have been excellent. The toe has been well broken and the fragmentation in general is better than with 9-in. holes. Not as much heave results from this blasting and the broken material usually stays within the boundaries of the track.

There are fewer holes to load in a shot and they are larger in diameter which means that the powder and stemming are more easily introduced and the holes loaded more rapidly. Less primacord is also necessary because of fewer holes in the blast. Less jackhammering is needed and the powder for secondary blasting is only about one half of one per cent of our total powder. We are gratified with the results obtained with this system, and steps are being taken to convert to 12-in. rigs.

Papers were presented at the annual meeting of the Arizona Section on Dec. 7, 1948.

Results of Tests on Mudcapping, Insert Bits, and Heavier Tools at Castle Dome

By M. M. STOVER • MIAMI, ARIZ.; MEMBER, AIME

mudcapping

Plugging boulders was abandoned in favor of mudcapping in December 1946. This was the result of four months' experimental work with the two methods. During this period, plugging costs were $1.025 per boulder compared to a cost of $0.869 for mudcapping. Results indicated that this cost could be further reduced as crews became more familiar with the method.

During 1947 boulders were broken by using sixty per cent special gelatin dynamite. In September 1947 experiments were started using army demolition powder known as M-3. These experiments indicated that M-3 would further reduce the cost and so it was adopted in January 1948.

Cost Comparison of the Two Explosives

Number Boulders Broken	Total Costs	Unit Cost
60% Special Gelatin 1947		
14,385	$10,269.97	$0.714
M-3 Jan. 1 to Nov. 1, 1948		
15,854	$6,754.92	$0.426

Cost reduction has been due to three factors: (1) less than ½ as much M-3 is required as sixty per cent gelatin; (2) lower price for M-3; and (3) increased labor efficiency. Men experience no ill effects from handling M-3.

Commercial blasting caps are not powerful enough to develop the full strength of M-3, and frequently fail to detonate it. Therefore it has been necessary to tie a 9-in. length of primacord around each cap before inserting it into the powder. No misfires have resulted from using this length of primacord and results indicate the full strength of the powder is developed. Boulders are fired in groups of 100 or less by instantaneous electric caps connected in series. Power is supplied by a hand operated blasting machine.

insert churn drill bits

At the request of the National Supply Co., a 9-in. churn drill bit with Kennametal inserts was given a trial. The bit started two holes and drilled a total of 71 ft in nine hours. The ground was medium hard and was fractured to 15 ft below the collar. Casing was driven using a steel-plate drive head. The bit was removed after 71 ft because each of the three inserts had broken about 1-in. from the outside end. The bit thus had no reaming surface left. The cutting edges remaining were as sharp as when the bit was new.

The face of the bit consisted of three inserts, 1-in. wide and 1¾-in. deep. The outside, or reaming edges were spaced 120 degrees apart. One insert was slightly longer than the other two thus placing the intersection of the inserts off center. The circumference was flattened between inserts which allowed three small water courses. The face was slightly concave.

Disadvantages of the bit were (1) failure of the inserts; (2) not enough reaming surface and; (3) water course too small.

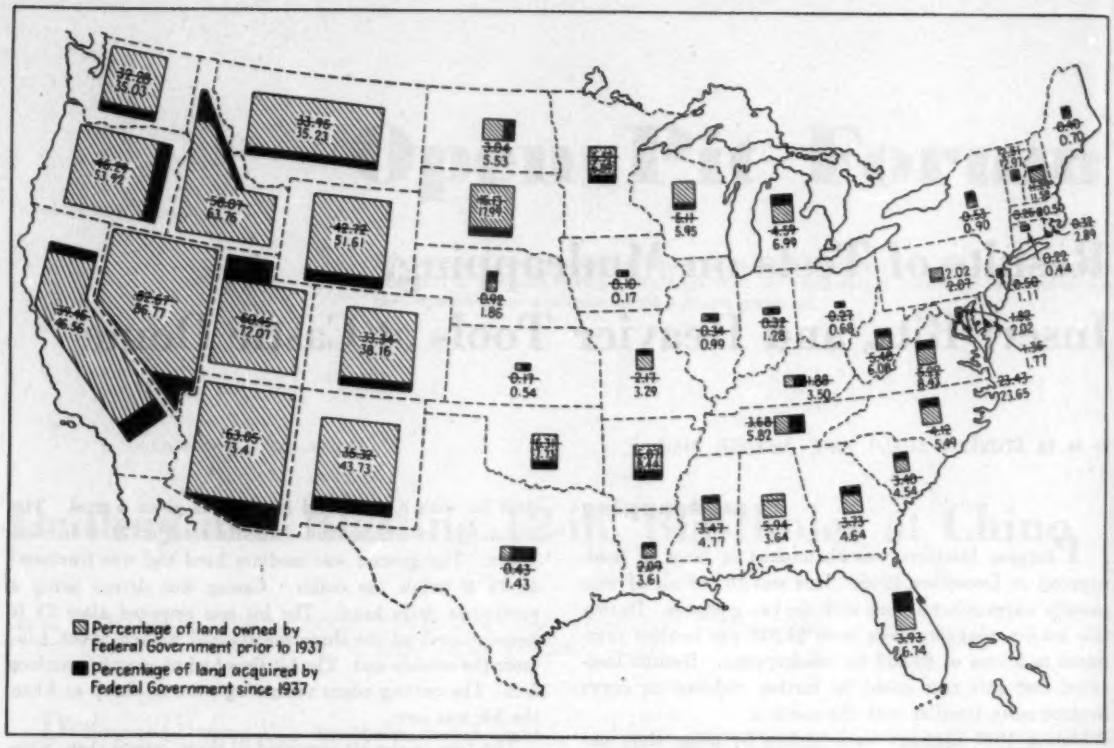
7-in. diameter tools

Heavier tools have been installed on two drills in an attempt to increase efficiency in the harder areas of the mine. This was done by increasing stem diameters from 6½ to 7 in. The increase in diameter has added about 400 lb to the tools. The weight of the new tools, with a new bit is approximately 3400 lb.

Comparison of Drilling Rates Between the Two Sets of Tools

	Feet Drilled	Number Shifts	Feet per Shift
7 in. Tools	6,827	93.5	73.1
Minus 6½ in. Tools	10,372	177.4	58.5

The test drilling has not all been in the most refractory areas, but the large and small tools have had comparable drilling. No decrease in rope life has been experienced. Earlier replacement of the rubber shock absorbers in the spudding sheave and tail sheave is indicated, but general maintenance appears to favor the large tools. Bit footage is practically the same as with the lighter tools.


Percentage of land owned by Federal Government prior to 1937
Percentage of land acquired by Federal Government since 1937

Typical of the governmental trend toward expanding its sphere of control is the increasing percentage of land coming under the ownership of the Federal Government by the purchases of some thirty or forty Federal departments.

Government in Your Hair

BY RICHARD W. SMITH • ASSISTANT MANAGER, NATURAL RESOURCES DEPT., CHAMBER OF COMMERCE OF THE UNITED STATES; MEMBER, AIME

Why are we losing our liberties? (1) . . . because our local chambers of commerce come to the National Chamber's annual meeting, vote for a policy on federal economy, and then go to Capitol Hill and ask for a federal project for their area. (2) . . . because our mining men ask for a subsidy to mine submarginal deposits that can't be economically mined in a free economy. (3) . . . because 18,000 men and organizations all over the country recently wired or wrote a Congressional committee asking that the Army Engineers be exempt from the President's power to reorganize the Executive Branch of the government under the recommendations of the Hoover Commission.

In the eyes of Capitol Hill and in the thinking of an ever increasing number of people throughout the country, you businessmen are not capable of running your own business for your own good or for the best interest of the country. Whether you like it or not the government is in your hair.

land one fourth Government owned

Twenty-five per cent of the United States is now owned by the federal government and the percentage is steadily growing by the purchases of some thirty or forty federal departments. In the West, the situation is much worse than in the East. Some 54 per cent of the eleven Western states is in federal ownership. The percentages of individual states range from 35 per cent of Washington to 87 per cent of Nevada. No wonder that Nevada, with 87 per cent of its land removed from state and local taxation has to legalize gambling to obtain revenue. About 46 per cent of California is federally owned. This federal ownership of the West includes national parks, national forests, Indian reservations, grazing districts, military reservations, reclamation projects, present and proposed, and scattered public domain lands that were too poor to be worth homesteading in the days

(Continued on p. 39 in back of magazine)

ALL INSTITUTE SECTION

APPEARING IN:
- MINING ENGINEERING
- JOURNAL OF METALS
- JOURNAL OF PETROLEUM TECHNOLOGY

To Members of the AIME:

For three years your Institute has been operating at a deficit, caused primarily by the increased cost of printing. This deficit has been largely met by borrowing from certain of the Funds which have been established for specific purposes by their contributors. Including an estimated $50,000 loss in operations for 1949, these borrowings will have reached the staggering sum of $150,000 by the end of the current year. Obviously, the Institute cannot continue to function on this basis.

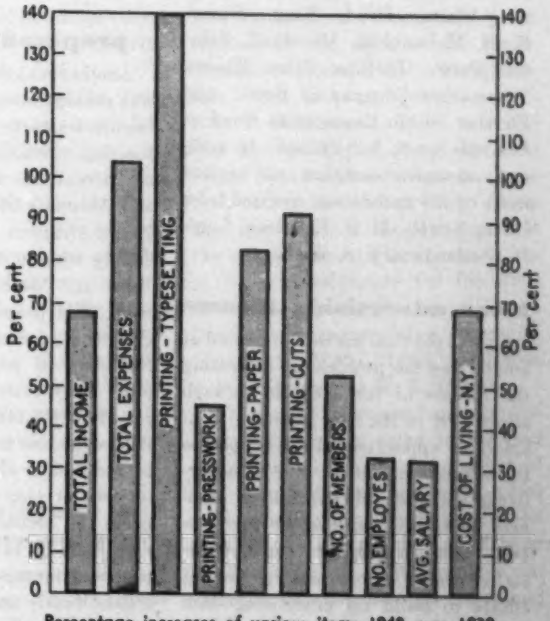
The Institute's main sources of revenue are advertising and membership fees. Every effort is being made to increase advertising revenue and to this end a new publication policy has been adopted whereby we put out three magazines, each in specialized fields, instead of *Mining and Metallurgy* and the four *Technologys* as heretofore. When these magazines become well established we have every reason to expect that the advertising revenue will be considerably greater than it was, but it may take three years to reach this goal. As to membership dues, a comparison with those of the other Founder Engineering Societies shows that ours are the lowest.

Taking due account of these two factors, the Section delegates at the San Francisco meeting recommended to the Board of Directors that a ballot be submitted to the membership to provide for an increase in dues, for a three-year period commencing in 1950, of $5 for Members and Associate Members and $2 for Junior Members. The Board of Directors unanimously approved the recommendation of the Section delegates.

It is estimated that this increase in dues will amount to approximately $50,000 per annum, which would permit a balanced budget in 1950 based on 1949 estimated income and expenditures. At the end of the three-year period another referendum vote will be taken, at which time dues for the succeeding years will be determined, based upon the conditions then prevailing.

A ballot will be sent to each voting member of the Institute in the latter part of May and you are urged to vote affirmatively in accordance with the recommendation of the Section delegates and the Board of Directors.

L. E. YOUNG
President



Percentage increases of various items 1948 over 1939.

Big Turnout of Directors Studies Vital Institute Problems at Six-Hour March Board Meeting

Nineteen Directors—a majority of the Board—spent six hours with their sleeves rolled up discussing important Institute problems at the meeting in New York on March 16. One out-of-town Director wrote back after returning home that he would come to the next meeting prepared with a knapsack and sleeping bag. A new procedure was tried for the first time: the usual monthly luncheon meeting of the Executive and Finance Committees was dispensed with, and instead the entire Board gathered at the Engineers' Club for a 12:30 luncheon and informal session without guests. Then two hours later, the regular open meeting got under way, and lasted until ten minutes to seven. President Young presided, the other Directors present being Messrs. Alford, Daveler, Elkins, Head, King, Kinzel, Kraft, McLaughlin, Meyerhoff, Pehrson, Peirce, Phillips, Price, Rhines, Schumacher, Suman, Swift, and Fletcher. T. B. Counselman acted as alternate for S. J. Swainson. In addition, absentee comment on various items on the agenda was received from Oliver Bowles, H. N. Eavenson, Louis D. Gordon, and T. S. Washburn.

more advertising income

One of the vital matters discussed at length was the problem of increasing the income of the Institute through advertising in the new journals. Considerable opposition had developed to the suggestion that an over-all advertising manager, or publication manager, be secured, at least for the present. The Petroleum Branch, especially, wished to contiuue its present efforts to build up advertising with only its staff at the Dallas office. The problem was believed most critical with the *Journal of Metals*, and authority was voted to secure an advertising solicitor immediately for this magazine. Mr. Schumacher, chairman of a small committee that had been appointed to consult with advertising men, reported their views, and Theodore Marvin gave the group the benefit of his experience as both a "space" salesman and buyer. Wheeler Spackman reported increased billings in the first quarter for *Mining Engineering* compared with *Mining and Metallurgy* last year, in spite of the loss of some advertising to the *Journal of Metals*. Advertising income for the three new journals should, it is believed, exceed that of last year by at least $30,000. "Publishers' representatives" may be used to augment regular staff coverage.

proposed dues increase

Another matter of great importance was consideration of the action of the Section Delegates at the San Francisco meeting, recommending to the Board an increase in the dues of Members and Associate Members of $5, and of Junior Members of $2, for three years ending with 1952. The Committee on Ways and Means had been asked to study this proposal, and Mr. Kraft, chairman, presented a summary of the financial condition of the Institute. If advertising income could be raised to $85,000 this year, and certain economies made, the deficit might be reduced to about half what it was in 1948, or some $42,000. This would bring the accumulated deficit for recent years up to about $150,000. The proposed increase in dues should increase yearly income by $55,000 to $60,000 for the three years, which would slightly more than offset the borrowings that have been necessary to meet the deficit. In 1952 a referendum would be taken as to whether or not the increased dues should be continued in the light of conditions at that time. The Board voted to accept the recommendation, and to conduct the required referendum of the membership. If the vote favored the increase, the necessary change in the bylaws would be voted on at the June meeting of the Board.

Other proposed changes in the bylaws to be acted upon by the Board at its June meeting will restore Jan. 1 as the date when dues become payable, with three months of grace allowed before members cease to be in good standing and the journals are cut off; and will dispense with the grade of Junior Foreign Affiliate at the end of 1949. The date when dues become payable had been changed to Oct. 1, but to increase the efficiency of work in the Institute's accounting department it is felt that mailing of the bills should be staggered through the months of September, October, November, and December.

Annual Meeting in St. Louis?

Shortly before the Board met, an invitation had been received from the St. Louis Section, the St. Louis Chamber of Commerce, and the St. Louis Convention and Publicity Bureau, inviting consideration of St. Louis as the scene of the Annual Meeting in 1951. Time had not permitted mature consideration of the proposal, so acceptance was postponed until the April meeting of the Board.

Mr. Schumacher, chairman of the Committee on Local Section Appropriations, reported his difficulties in making the available money—which the Board had set at approximately the same figure as last year, $9000—meet the needs of the Local Sections. Many had offered excellent arguments for increased allocations, up to $600 each though the Bylaws set a limit of $400. The Board was sympathetic to the needs of the Local Sections, many of which were believed to be doing an exceptionally fine job, but, with the depleted finances of the Institute, could not see its way to raise the total appropriation. The Local Section reports were studied carefully, and the fairest division possible was made. However, to alleviate the situation to some extent for the Local Sections, each was voted 10% of the initiation fees paid by all new members in its territory. This will be effective with the April elections. Thus a Local Section will receive an extra $100 if fifty new Members or Associate Members are elected from its area in the course of a year.

cost-cutting ideas

Mr. Elkins reported that the Petroleum Branch was planning issuance of a Directory of its members in the early summer, to be financed from its own funds. No complete Institute Directory is to be published until 1950. He also offered various recommendations designed for increased economies and efficiencies in the conduct of Institute affairs, suggesting that committees be appointed to study these matters. He was assured, however, that the Board and staff had already given close study to some of the suggestions and were keenly alive to the need for cutting costs in every way possible consistent with maintaining the essential services of the Institute. Particularly, Mr. Elkins thought that all meetings should be self-supporting in justice to those who could not attend them. In this the Board fully concurred, and voted that registration fees and other charges at all Annual, Regional, and Divisional meetings be set at such figures that they would be self-supporting to the fullest extent possible.

Chairmen of the Institute's standing committees for 1949-50 were announced and the complete committee personnel, with Local Section and Student Society officers, will be published in the June issues of the three journals. Certain inactive committees will be discontinued.

The Committee on Nominations for Institute Officers reported some difficulties in interpreting the rules and selecting candidates that properly represented the professional and geographical divisions of the membership. President Young was therefore authorized to appoint a committee of three to revise and clarify the "Instructions and Advice" to members of this Committee.

segregating Transactions material

Some members had reported a preference that the Transactions volumes be published by Divisional subjects, as in the past, rather than combining all the technical publications of a Branch, as is the plan for the future. Mr. Price, especially, reported the wish of the Coal Division that its papers be segregated, both in *Mining Engineering* and in a Transactions volume. This could be done, it was reported, either by holding the type for a year or more, or by separate offset printing of the desired papers, but either would be more costly than the present practice. The Board felt that the matter should be reconsidered before the end of the year, with relative costs considered.

Suggested plans for special committees of the Directors to consult frequently with the editorial boards of the three Branch journals were discussed, but it was felt that if Directors keep in close touch with the officials of the Branch they represent, and the Secretary keeps himself apprised of the wishes of members at the Local Section level, no further organization should be necessary. A continuous sampling of reader opinion on *Mining Engineering* is under way for the guidance of the editorial and advertising staffs.

delegates and representatives

Among the routine matters disposed of were the following: W. H. Carson was appointed an official delegate to the World Engineering Congress in Cairo. E. H. Robie was appointed as a director of the Engineering Societies Personnel Service. A. Rodger Denison was appointed an AIME director of the American Geological Institute for the term ending November, 1949, and Joseph L. Gillson for the term ending November, 1950. Approval was given the proposal to invite G. Borelius, a professor at the Techniska Högskolan, Stockholm, as Institute of Metals Division Lecturer for 1951. Francis B. Foley was appointed to represent the AIME on the Engineers Joint Council Committee on Collective Bargaining by Engineers in Professional Work.

Howard A. Herder was named to represent the AIME on the Washington Award Commission for a two-year term, to May, 1951. Gail F. Moulton was appointed to succeed Ralph M. Roosevelt as an AIME representative on United Engineering Trustees for a four-year term expiring in October, 1953. R. M. Brick and Francis B. Foley, with A. W. Grosvenor as alternate, were appointed official delegates to the meeting of the American Academy of Political and Social Science at Philadelphia, April 8-9. Approval was given to the continuance of the Alloys of Iron Research as an AIME-sponsored Engineering Foundation project for 1950 and 1951. A price of $3 to members and $5 to nonmembers was set for the translation, in one volume, of the old German books, "Probierbuchlein" and "Bergbuchlein," soon to be published.

L. E. Young was named to represent the AIME on the John Fritz Medal Board of Award for a four-year term ending in October, 1953. Attention was called to the fact that it is the turn of the AIME representatives to name a candidate for the Fritz Medal this year, and nominations are invited. Suggestions may be sent to Harvey S. Mudd, Louis S. Cates, Erle V. Daveler, or W. E. Wrather.

The sincere thanks and appreciation of the Board was voted to the San Francisco Section for its conduct of the Annual Meeting, and thirty copies of the 75th Anniversary Volume of the AIME were ordered sent to William Wallace Mein, Jr., Chairman, for distribution to committee chairmen and other active workers.

Donald H. McLaughlin Nominated for President in 1950

Donald H. McLaughlin, president of the Homestake Mining Co. and a Vice-President of the AIME, has been named to head the ticket for new Board members in 1950 by the Committee on Nominations for Institute Officers. Nominations for Vice-President are Andrew Fletcher and Robert W. Thomas, both of whom currently hold the same office, but whose present terms expire next February. The six other Directors chosen are: Francis B. Foley, superintendent of research for The Midvale Co., Philadelphia; Edward Meagher, treasurer of the Texas Gulf Sulphur Co., New York; Howard I. Young, president of the American Zinc, Lead and Smelting Co., St. Louis; Harold Decker, assistant manager of the Pan American Production, Pipe Line, and Gas Co., Houston; and C. V. Millikan, Amerada Petroleum Corp., Tulsa. Of these, only Mr. Millikan is currently a member of the Board.

Donald H. McLaughlin

At its June meeting the Board will name a ninth candidate, and if no supplementary tickets are named by Sept. 1 the above slate is automatically elected. In that case, a new Vice-President will also have to be elected by the Board, owing to the elevation of Dr. McLaughlin to the Presidency.

Where to Split the Metallurgists?

Is an operator of a cyanide plant, a copper leaching plant, a roasting plant, or a mercury distillation plant primarily a mineral beneficiator or an extractive metallurgist? The officials of the Minerals Beneficiation Division and of the new Extractive Metallurgy Division each claim these and some other similar fields, in whole or in part. The practical difficulty, so far as the AIME is concerned, is that the technical papers of the former Division are to be published in MINING ENGINEERING and of the latter in the *Journal of Metals*. Even some of the individual members immediately concerned are by no means certain as to whether they are more closely allied to the Mining or to the Metals Branches, into which the Institute is now broadly divided. A pyrometallurgist, working in a copper smelter, a field of activity not even claimed by the MBD, writes that he works in a mining district, all his friends are mining and millmen, he cannot understand and has no interest in the type of papers published in *Metals Technology*, and would like to see all smelting papers published in *Mining Engineering*. But most members of the Committee on Reduction and Refining of Copper do not appear to agree with him.

Much thought has been given to the problem but no thoroughly satisfactory solution has been found. Authors' wishes as to the medium of publication will be considered, but ultimate decision will rest with the Technical Publications Committee. For the time being, members in the controversial fields should pick the journal that they think likely to be of major interest to them, and then watch the list of all technical papers published. If they note one in which they are interested published in a journal to which they do not subscribe, they can obtain a copy for 75 cents. Fortunately it does not seem likely that cases of this kind will be too numerous.

Expensive Advertising

A double-page spread in the February *Fortune* is devoted to the wonderful results that advertisers get in that magazine. Among other items is: "A page in the August issue resulted within ten days in a closed deal for 3,000 square feet of flooring." Business must be pretty bad.

New Arizona Scholarships

A grand total of twelve scholarships at the University of Arizona and eight at Arizona State College have been established for students of mining, metallurgy, and allied fields by the Phelps Dodge Corp. One first year scholarship will be given each year at the State College, and during the first year, comparable grants will be set up for the second, third, and fourth years. The plan at the University of Arizona is the same, but double the number of awards will be made, and graduate studies are also included. Eligibility is limited to Arizona residents.

Paul G. Hoffman to Speak at ISD May Dinner

Paul G. Hoffman, ECA administrator, will be the speaker at the annual Iron and Steel Division May dinner on May 25, his subject, The ECA and You. The dinner will be held at the Statler Hotel in the Georgian Room at 7 p.m., preceded by a social hour in the foyer to the Georgian Room. Tickets are $6. Please make reservations through the Secretary of the ISD, AIME, 29 West 39th St., New York City 18.

Correction, Please

We received the following letter from R. G. Knickerbocker, chief, Rolla branch, metallurgical division, Bureau of Mines. We wish we could accept Mr. Knickerbocker's kind explanation of the error, but fear that our printer might get angry and any way we were brought up to be relatively honest.

"In the interest of the manganese industry, and especially the Electro Manganese Corp. at Knoxville, Tenn., I believe it will be necessary to correct the printer's mistake made in the fourth paragraph of the second column on page 97 under electrolytic manganese. (March Annual Review on Ferroalloy Metals.) The price of elec-

trolytic manganese effective Jan. 1, 1949, has been reduced to $0.28 per lb and not to $1.28 per lb. No doubt this is perfectly clear to those technically concerned with the manganese industry but to a great many others concerned with the critical status of treatment of low-grade domestic manganese ores this figure of $1.28 might be extremely misleading."

1949 Annual Banquet Souvenirs

The miniature gold pan, made of sterling silver, commemorating the discovery of gold in California, has caught the eye of many a member.

The pins were presented to all ladies attending the 1949 banquet in San Francisco.

Any member interested may secure one of these pins at a cost of $1.50.

Pins in 18 kt. gold, as well as in platinum, may be had at special prices.

To order, direct request and check to:

Mr. H. A. Sawin,
Yuba Manufacturing Co.,
San Francisco 4, Calif.

New York Ladies to Entertain Husbands

The members of the New York Section of the Woman's Auxiliary to the AIME will entertain their husbands on the evening of Friday, May 13, at the Engineering Woman's Club, 2 Fifth Ave. Cocktails will be served at 6 p.m., followed by dinner and entertainment, all for $3.50 per person.

Among the Student Associates

Louisiana State University

The Student Chapter at LSU has been reactivated, following a wartime cessation of activity. The first meeting, on Feb. 24, was attended by almost 300 students and business men, who heard Francis Anderson, of the Halliburton Oil Well Cementing Co., Duncan, Okla., speak on the use of plastics in unconsolidated sands. The Chapter's officers are James W. Law, President; Jack Simpson, Vice-President; and Jerry Shea, Secretary-Treasurer. H. F. Winham of the Shell Oil Co., Donaldsville, La., has returned as industrial advisor.—*Mahlon F. Manville, Corresponding Secretary.*

Lafayette College

The popular "Story of an Ore Sample" was one of three films shown at the Feb. 22 meeting of the John Markle Society. The Goodrich Rubber Co. contributed "On the Way Out," a film on the use of conveyor belts on coal mines; and the production and use of coal were presented in the last film.

Professor Leist of Lehigh University was there to interest members in the AIME Lehigh Valley Section's essay contest. Sixty of the Society's membership of 75 attended the meeting, later enjoyed refreshments in the ore dressing room.—*J. Siergiej, Secretary.*

University of New Hampshire

Four years of experience with a geophysical crew in the West were presented before the University of New Hampshire's Student Chapter at the January meeting by Harold E. Webster, Jr., geology instructor at the university. Many of the Chapter's June graduates hope to take further courses in oil geology, and so Mr. Webster's discussion of methods, equipment, the work of crew members, and the advantages and disadvantages of this type of work was particularly beneficial to them.

Geologic problems and methods in coal mining, as well as labor problems in the industry, were incorporated in a slide-illustrated talk on coal mining by Ralph Meyers, our Student Chapter's Faculty Advisor, at the February meeting. Professor Meyers' talk emphasized the vast importance of coal in our economy, noting that the petroleum field tended to have a greater place in present day news.—*Marston Chase, Corresponding Secretary.*

University of Southern California

Archibald M. Laurie was elected President of the Student Chapter at USC during the Feb. 16 meeting. Supporting him are Vice-President Richard S. Davis; Secretary Robert J. Fernandes, and Treasurer Robert R. Shaffer. The membership and program committees are headed by Richard Davis and Richard Brazier, respectively. John P. McGriff is the Chapter's parliamentarian.—*Carrol M. Beeson.*

University of Wisconsin

Not nuts and bolts, but a complete delectable dinner, was prepared in the University's metallurgical laboratory furnaces for the Mining Club's February dinner and business meeting. Steeled by their metallurgical meal, the members went on to make plans for St. Patrick's Day observances.

Snow art sculptured by the Mining Club at Michigan College of Mining and Technology took first prize at the winter carnival. The scene commemorates the '49 Gold Rush.

The repast was served at the school's new foundry, and guest speaker Chester V. Nass grasped a fine opportunity to review the past and present in foundries and outline some of the engineering problems extant in that field. Mr. Nass, vice-president of the Pettibone Mulliken Corp., Chicago, and Student Counselor for the Chicago Section, AIME, also reviewed labor-management relations in his industry, and sounded an optimistic note for future job-seekers.—*Arnold D. Arnaut, Public Relations.*

Yale University

Richard J. Christine and I. J. Hook, both of the American Brass Co., addressed the Yale Metallurgical Society on Dec. 2 and Feb. 15, respectively. Mr. Christine told members what industry expects of newly graduated metallurgists; Mr. Hook discussed Anaconda copper production in Montana, and showed a movie on the subject. Discussion periods followed both meetings and proved to be of considerable worth to the students. —*Voluntine T. Potter, Secretary.*

What Went on at Recent Local Section Meetings

SECTION	DATE	PLACE	PRESIDING OFFICER	ATTENDANCE	SPEAKER, AFFILIATION, AND SUBJECT
Arizona, Morenci Subsection	Mar. 7	Longfellow Inn, Morenci	L. O. Ormsby	30	L. L. McDaniel, mill superintendent, Phelps Dodge Corp., on AIME Annual Meeting. L. O. Ormsby, mine superintendent, Phelps Dodge Corp., on trucks for mine haulage.
Black Hills	Mar. 24	Lead, S. Dak.	Fremont Clarke	52	Fremont Clarke, Lithium Corp. of America, on AIME Annual Meeting.
Boston	Mar. 7	Smith House, Cambridge	George P. Swift	48	Frank R. Milliken, National Lead Co., on Ilmenite, Titanium Dioxide and Titanium. Carle R. Hayward, MIT, on R. H. Richards—reminiscences.
Chicago	Feb. 2	Chicago Bar Association	L. R. Berner	125	S. J. Creswell, Carnegie-Illinois Steel Co., on developments in the Bessemer Process.
Chicago	Mar. 2	Chicago	H. A. Herder	54	J. R. Van Pelt, Jr., Battelle Memorial Institute, on tools for modern prospectors.
Colorado	Feb. 23	University Club, Denver	M. I. Signer	34	M. I. Signer, Dean, Colorado School of Mines, on mineral industry education.
Columbia	Mar. 4	Davenport Hotel, Spokane	Howard P. Sherman	24	C. Y. Garber, chairman, Columbia Section, AIME, on AIME Annual Meeting.
Detroit	Mar. 21	Detroit	Frederick P. Bens		Harold Hunsicker, Aluminum Co. of America, on precipitation hardening in aluminum alloys.
Detroit	Feb. 21	Detroit			R. K. Hopkins, M. W. Kellogg Co., on the Kellogg Process of ingot production.
El Paso Metals	Mar. 9	Hotel Cortez, El Paso	E. M. Tittman	26	F. E. Hewitt, asst. prof. of education, Texas Mines and Met., film taken in Russia, 1936.
Gulf Coast	Feb. 15	YMCA, Houston	E. B. Miller, Jr.	122	Olin G. Bell, Humble Oil Co., on deep drilling in the Gulf Coast area.
Lehigh Valley	Dec. 6	Bethlehem, Pa.	M. L. Fuller	104	W. E. Wrather, director, USGS, on recent trip to the Near East.
Mid-Continent	Mar. 14	Bartlesville, Okla.	John P. Hammond	151	Herman H. Kaveler, Philips Petroleum Co., on cases of increasing well densities.
Montana	Mar. 1	Butte	J. Hollis McCrea		H. G. Satterthwaite, Anaconda Copper Mining Co., on the AIME Annual Meeting.
North Pacific	Feb. 17	Rose's Highway Inn, Seattle	W. C. Leonard	39	H. K. Benson, emeritus professor of chemistry, Univ. of Washington, on agricultural production problems.
North Pacific	Mar. 17	Rose's Highway Inn, Seattle	Kenneth Anderson	48	J. Harveson, Standard Oil Co., of California, motion pictures, "Desert Venture"; "City of Destiny"; "Winter Olympiad."
Oregon	Jan. 21	Nortonia Hotel, Portland	Hollis Dole	23	William E. Caldwell, Oregon State College, on northwest strontium mineral deposit.
Oregon	Feb. 25	Mallory Hotel, Portland	Hollis Dole	22	James H. Jensen, Pacific Carbide and Alloys, on calcium carbide for Pacific northwest industries.
Oregon	Mar. 18	Mallory Hotel, Portland	Hollis Dole	31	Pierre R. Hines, consulting engineer, on conveyors and materials handling.
Pittsburgh	Mar. 7	Mellon Institute of Industrial Research	Stephen Krickovic	300	C. H. Snyder, president, Sunnyhill Coal Co., on Colmol continuous mining machine.
Southern California	Feb. 18	Los Angeles	E. O. Slater	70	Richard W. Smith, U. S. Chamber of Commerce, "Government in Your Hair."
Southwest Texas	Mar. 9	Corpus Christi	Houston Parrish	166	George Howard, Stanolind Oil & Gas Co., on proper cementing of casing.
St. Louis	Feb. 18	Hotel York	H. A. Neustaedter	52	Frank G. Breyer, Singmaster & Breyer, on exporting American know-how.
Utah	Feb. 24	Salt Lake City	J. C. Landenberger, Jr.	56	C. J. Christensen, Dean, School of Mineral Industries, University of Utah, on prospectors and Indians. Elroy Nelson, Univ. of Utah, on local taxation in mining industry.
Utah	Mar. 17	Newhouse Hotel, Salt Lake City	J. C. Landenberger, Jr.	44	D. C. Houston, Kennecott Copper Co., "Personnel is People."

Omaha Public Library
Reference Dept.

Current Institute Papers

The following papers are available to Institute members in the three journals. Each member will receive one classification in the journal of his choice. Members may obtain papers in the two remaining classifications by purchasing the indicated issue of the journal at $0.75 per copy. There are no separate copies of the individual papers. ME means Mining Engineering, JM Journal of Metals, and JPT Journal of Petroleum Technology.

Mining Papers

The Heavy Mineral Deposits of the East Coast of Australia—By N. H. Fisher. (*November Mining Technology.*)

Underground Anemometry — By C. M. Smith. (*January Mining Engineering.*)

Beneficiation of Industrial Minerals by Heavy-media Separation—By G. B. Walker and C. F. Allen. (*January Mining Engineering.*)

Importance and Application of Piezo-Electric Minerals—By Hugh H. Waesche. (*January Mining Engineering.*)

Texas White Firing Bentonite—By F. K. Pence. (*January Mining Engineering.*)

The Application of Screening and Classification for Improved Fine Anthracite Recovery—By W. Julian Parton. (*February Mining Engineering.*)

Operational Statistics of a Marion 5560 Power Shovel—By G. B. Clark and G. L. Reiter. (*February Mining Engineering.*)

The Flotation of Copper Silicate from Silica—By R. W. Ludt and C. C. DeWitt. (*February Mining Engineering.*)

Recent Trends in Asbestos Mining and Milling Practice—By M. J. Messel. (*February Mining Engineering.*)

A Technical Study of Coal Drying—By G. A. Vissac. (*February Mining Engineering.*)

Metals Papers

Transient Plastic Deformation—By R. P. Carreker, J. G. Leschen, and J. D. Lubahn. (*September Metals, Technology.*)

Oxide Films Formed on Metals and Binary Alloys. An Electron Diffraction Study—By J. W. Hickman. (*December Metals Technology.*)

Development of the Modern Zinc Retort in the United States—By H. R. Page and A. E. Lee, Jr. (*February Journal of Metals.*)

The Effect of Strain-temperature History on the Flow and Fracture Characteristics of an Annealed Steel—By E. J. Ripling and G. Sachs. (*February Journal of Metals.*)

Relation Between Chromium and Carbon in Chromium Steel Refining—By D. C. Hilty. (*February Journal of Metals.*)

The Densification of Copper Powder Compacts in Hydrogen and in Vacuum—By Charles B. Jordan and Pol Duwez. (*February Journal of Metals.*)

Influence of Composition on the Stress-Corrosion Cracking of Some Copper-base Alloys — By D. H. Thompson and A. W. Tracy. (*February Journal of Metals.*)

Calendar of Coming Meetings

MAY

2 Pittsburgh Section, AIME. President L. E. Young.
2 Boston Section, AIME.
2-4 ASME spring meeting, New London, Conn.
2-5 American Foundrymen's Society, 53rd annual meeting, St. Louis.
5 Reno Branch, Nevada Section, AIME.
6 Columbia Section, AIME.
6-7 American Institute of Chemists, annual meeting, Chicago.
7 Chicago Section, AIME. President's Night.
8-12 AICE, Tulsa, Oklahoma.
9 Mid-Continent Section, AIME.
9-12 American Mining Congress, coal convention and exposition, Public Auditorium, Cleveland.
10 East Texas Section, AIME.
11 El Paso Metals Section, AIME.
11 San Francisco Section, AIME.
11-13 Engineering Institute of Canada annual meeting with International Management Congress hemisphere meeting, Chateau Frontenac, Quebec.
14 Northwest Industrial Minerals Conference under auspices of Columbia Section, AIME, Spokane.
16 Detroit Section, AIME. A. A. Cooley on metallic sheet.
May 16-June 3 U.N. Scientific Conference on Conservation and Utilization of Resources, New York.
17 Gulf Coast Section, AIME.
17 Washington, D. C., Section, AIME.
18 Southwest Texas Section, AIME.
19 Carlsbad Potash Section, AIME.
19 North Pacific Section, AIME.
19 Utah Section, AIME.
19-20 Lake Superior Mines Safety Council, Duluth, Minn.
20 Oregon Section, AIME.
23 Alaska Section, AIME.
24 Montana Section, AIME.
25 Iron and Steel Division, AIME, annual May dinner, Statler Hotel, New York City.
25-26 American Iron and Steel Institute, general meeting, New York City.

JUNE

3-4 Central Appalachian Section, AIME, spring meeting, Blacksburg, Va.
5-10 SAE, summer meeting, French Lick Spring, Ind.
16 Engineering Foundation, 29 W. 39 St., New York City.
June 27-July 1 ASTM, 52nd annual meeting, Chalfonte-Haddon Hall, Atlantic City, N. J.
20-22 American Society of Heating and Ventilating Engineers, semi-annual meeting, Minneapolis, Minn.
20-24 AIEE, summer general meeting, New Ocean House, Swampscott, Mass.
20-24 National Society for Engineering Education, RPI, Troy, N. Y.
25-26 American Iron and Steel Institute, general meeting, N. Y. C.
27-30 ASME, semi-annual meeting, San Francisco.

JULY

9-23 Fourth Empire Mining and Metallurgical Congress, Great Britain.
13-15 American Society of Civil Engineers, summer convention, Mexico City.
15-24 Pan-American Engineering Congress, Rio de Janeiro.

AUGUST

23-26 AIEE Pacific general meeting, Fairmont Hotel, San Francisco.
26-Sept. 10 Engineering & Mining Exhibition, London, England.

SEPTEMBER

25-28 Regional Meeting, AIME, Neil House, Columbus, Ohio.
25-28 American Mining Congress, Western fall meeting, Spokane.
29-30 ASME, fall meeting, Erie, Pa.
29-Oct. 1 Colorado School of Mines, 75th anniversary celebration.
Sept. 30-Oct. 1 Southern Ohio Section of Open Hearth Committee, AIME, fall meeting, Deshler-Wallick Hotel, Columbus.

OCTOBER

5-7 Petroleum Branch, AIME, fall meeting, Plaza Hotel, San Antonio, Texas.
17-19 Institute of Metals Division, AIME, fall meeting, Allerton Hotel, Cleveland.
17-23 AIEE, 1949 Mid-West meeting, Netherlands-Plaza, Cincinnati.
20-21 Petroleum Branch, AIME, Elks Club, Los Angeles.
26-27 Joint Fuels Conference, ASME-AIME, French Lick Springs Hotel, French Lick, Ind.
28 Pittsburgh Section of Open Hearth Committee and Pittsburgh Section, AIME, annual fall meeting, William Penn Hotel, Pittsburgh.

NOVEMBER

1-5 Pacific Chemical Exposition, California Section, American Chemical Society, San Francisco Civic Auditorium.
2-4 American Society of Civil Engineers, fall meeting, Washington, D. C.
7-10 AIChE, annual meeting, Pittsburgh, Pa.
9-11 Industrial Minerals Division, AIME, Tampa, Fla.
12-14 Geological Society of America, annual meeting, Hotel Cortez, El Paso.

DECEMBER

8-10 Seventh Annual Conference, Electric Furnace Steel Committee, Iron and Steel Division, AIME, Hotel William Penn, Pittsburgh.

FEBRUARY 1950

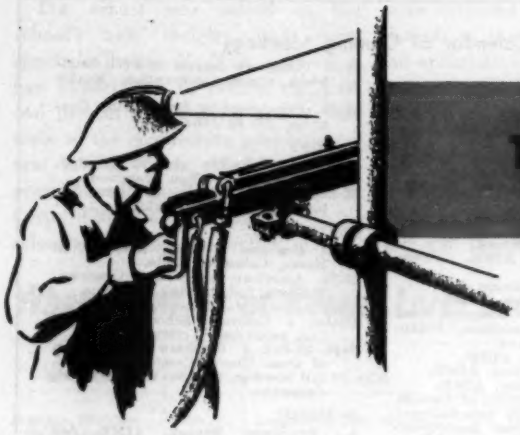
12-16 Annual Meeting, AIME, Statler (Pennsylvania) Hotel, New York City.

APRIL 1950

10-12 Open Hearth Conference, and Blast Furnace, Coke Oven and Raw Materials Conference, Netherland-Plaza Hotel, Cincinnati.

DECEMBER 1950

7-9 Eighth Annual Conference, Electric Furnace Steel Committee, Iron and Steel Division, AIME, Hotel William Penn, Pittsburgh.



THE DRIFT OF THINGS

. . . as followed by EDWARD H. ROBIE

For Peace or War?

Unquestionably, the North Atlantic Pact is an important milestone in international agreements destined to prevent war, but whether or not it will be more effective than previous treaties remains to be seen. The approach is quite different from the Briand-Kellogg treaty—the Pact of Paris—signed by fifteen nations in 1928, and subscribed to by others including Russia later. That was an out-and-out renunciation of war, which certain of the signers, notably Germany and Japan, did not take seriously, as subsequent events proved. A different type of agreement designed to prevent war was that embodied in the League of Nations, and the Permanent Court of International Justice, and latterly in the United Nations. A weakness in the last-named, of course, is the privilege of the veto power, which both Russia and the United States insisted on reserving and which Russia has used to excess. No joint action, such as the United Nations agreement implies, can work if one nation reserves the right to prevent action in cases where its own interests are involved. Another weakness is lack of police power to enforce its decisions. Thereby it can become little more than an international debating society. The world government movement, as is being conducted with some success by United World Federalists, would seem to be a much more realistic means of preventing war. Soviet Russia will have none of it, but might subscribe to it if the rest of the world did.

Heretofore military alliances have been notably unsuccessful in preventing war, as have all other means, but at the present juncture in world affairs, with Soviet imperialism rampant, some forceful repressive measures seem necessary. Russia has long shown an unco-operative spirit with the rest of the world. Appeasement gives no promise, having failed so signally with another totalitarian government imbued with the idea of re-forming the world.

The North Atlantic Pact might better serve its purpose of scaring off aggressors, and preventing war, if more nations joined it. We already have the treaty of Rio de Janeiro, signed in 1947, whereby the American nations pledge themselves to unite against any one that starts a war. This would seem to fit in with the new pact. If, now, all the rest of the world would enter into such a treaty and aggression were sharply defined, then the force that the United Nations lacks to back up its decisions would be provided and a large part of the aims of the world government advocates would be realized.

Russia's opposition to the present pact means one of two things—either that she herself has designs on still more neighboring countries, or that she doubts that the pact is designed merely to stop aggression. In view of her inexcusable attack on Finland before World War II, and her seizure of control of Czechoslovakia after the war, to cite but two examples, one may be pardoned for considering the first reason the paramount one.

Therefore, a military alliance against aggression, such as the North Atlantic pact, seems well justified at the present time and likely to be a deterrent to war, even though it may not prevent one. But the entire world should join such a pact—and then live up to it. In other words, the United Nations with a gun in its pocket.

We have no sympathy whatever with the minority that think Russia will do as she pleases as soon as she gets the atomic bomb and that therefore we should dispose of her as soon as possible. Not only would that be morally reprehensible, but the practical result of another war so soon after the last might easily be the overthrow of our system of government. It has already been undermined by two disastrous world wars, and if we cannot prevent another, then it is high time something different should be tried. Not that Communism gives hope of being anything better.

The best rule for the present, as we see it, is that to which Theodore Roosevelt gave voice: "Speak softly but carry a Big Stick." The Big Stick in this case is the North Atlantic Pact, with the requisite power to carry it out.

Encouragement for Our Teachers

Winston Churchill, in his fine address given at the Mid-Century Convocation of MIT, paid a well-deserved tribute to our American engineering schools: "We have suffered in Great Britain by the lack of colleges of university rank in which engineering and the allied subjects are taught. Industrial production depends on technology and it is because the Americans, like

the prewar Germans, have realized this and created institutions for the advanced training of large numbers of high-grade engineers to translate the advances of pure science into industrial technique—it is for that reason that their output per head and consequent standard of life are so high."

He might have added that for the same reason this country was the first to produce enough fissionable material to make possible the practical use of nuclear energy.

Our engineering schools have long been the target of critics who have complained of inadequate training. This view of a foreign observer should give the schools much encouragement.

Dr. Boyd Confirmed As Director

Mining men were glad to hear that Jim Boyd had finally been confirmed as director of the Bureau of Mines and no longer had to serve without a salary. In fact, we understand that his back salary is to be paid. Unfortunately, the directorship of the Bureau has for some years depended more than it should on politics. But fortunately Dr. Boyd is a comparatively young man, and able professionally, so perhaps, with a good record behind him, he can survive any change in the political complexion of the Administration, should one ever occur.

The delay in confirming Dr. Boyd as director is said to have been due to the opposition of John L. Lewis, who has no use for Secretary Krug, Dr. Boyd's boss. John L. was also able to bring political influence on Senator Millikin, of Colorado, who long was able to block the appointment but was finally overruled in the new Administration. When Lewis called the two-week strike of the coal miners, purportedly to call attention to the need for safer working conditions, the matter was brought to a head, and the Senate confirmed Dr. Boyd partly to show its independence of Lewis. Even so, eleven Senators voted against the appointment, with fifty favoring it. Perhaps the names of the eleven should be remembered. They were: Millikin, of Colorado, Brewster of Maine, Bricker of Ohio, Capeheart and Jenner of Indiana, Langer of North Dakota, Schoeppel of Kansas, and Wherry of Nebraska, all Republicans; with Johnson of Colorado, and Kilgore and Neely of West Virginia, Democrats.

The principal argument offered against Dr. Boyd was that he had not had operating experience in mining, and had had no contact with either the coal mining industry or with health and safety matters. Operating experience would not appear necessary to fill the job acceptably; and men with both coal and metal-mining experience combined with health and safety training are exceedingly rare.

The Accident Record

The real reason for the two-week shutdown of the coal mines was probably not so much as a memorial to coal miners who had been victims of 55,000 coal-mine accidents last year, as alleged, as it was to reduce the stocks of coal a bit, so as to afford better bargaining conditions when the time for setting a new contract comes up, on May 1. The shutdown had little practical effect, for coal demand has recently been much less than capacity, so that a large number of the miners have been working only two to four days a week. Were wages lower, which would permit lower coal prices, then more coal in relation to oil would be used, and it might be that the income of coal miners would be greater than at present. But high wages make the best selling point, even though the opportunity to get them is limited.

If the reason for the shutdown was really the one given, then the timing was not particularly propitious, for the news came out during the strike that in 1948 there were fewer accidents per ton of coal mined than in any previous year in history. As to fatalities, the record was not quite so outstanding, but still good: it was the fourth lowest year as to deaths in bituminous mines and the second lowest in anthracite mines. For both branches, 1010 men were killed last year and 54,100 injured. That is still not a record to be proud of, nor is the record of work injuries for all industries. Last year disabling work injuries amounted to 1,960,000, deaths 16,500, permanent disablements 1800; with 41,000,000 man-days of work lost, representing more than four billion dollars in wages. Automobile fatalities were around 32,000.

It's dangerous to be alive. Carelessness takes a bigger toll of life and health than war but is not nearly so costly in money.

AS&R's Golden Anniversary

On April 4 the American Smelting and Refining Co. celebrated its fiftieth anniversary. Receptions and entertainment were features of the day at many of its plants, and the employes of the headquarters office in New York were entertained at the Bankers' Club. Though the words "mining" and "milling" are not included in its name, its activities include these fields as well, and extend all over the world.

We have been visiting AS&R plants, and have been on friendly terms with AS&R men, for 35 years. We have found the plants well run by a fine lot of men who have been uniformly most generous and hospitable when we dropped around. Until we decided it was more important to buy a home than to be an AS&R stockholder we used to receive regular dividends, of modest amount but an excellent return on our small investment. AS&R men have written innumerable papers for the AIME, and have served on numerous committees, and in various capacities as officers. One is currently a Director.

The Company produces practically all nonferrous metals, to some extent at least, but is important in copper, lead, zinc, gold, and silver. Its interests are in both primary and secondary metals, and extend to fabricating. It operates several coal mines but so far as we know has kept out of the oil business. Much of its raw material is purchased from small shippers but much smelting and refining is done for large companies too, like Kennecott, for instance.

So we add our salute to the others that AS&R has received. For half a century it has conducted important units in a basic American industry with conspicuous success to itself and to its stockholders, and in a highly creditable manner as a national institution. May the next half century add further to its stature.

News of AIME Members

Wayne J. Ahl is a junior engineer with the Inland Steel Co. His address is 336 W. Division St., Ishpeming, Mich.

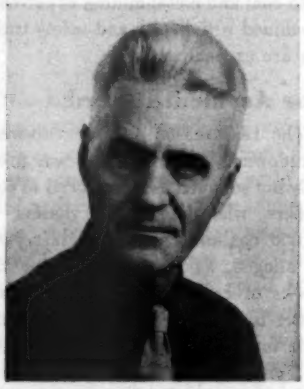
L. W. Allen, on six months' leave from his post as underground manager of Nchanga Consolidated Copper Mines Ltd., Chingola, N. Rhodesia, spent the first three months of that leave traveling some 6000 odd miles, doing a little fishing here and there, taking in the bright lights of Johannesburg and one or two other cities in S. Africa, and is spending the last three months on his farm, quite close to the coast in a beautiful part of South Africa. The fishing is good, and with the farm to potter about on, he expects to enjoy himself. Nchanga Consolidated is still busy with an expansion program and has a big construction and development program on hand. The tonnage mined has been steadily increasing and just before he left had reached a record of some 114,000 tons a month. The first increase in capacity is designed to handle 150,000 tons a month, but it looks as if the plant will have a rather larger capacity than that for which it was designed.

Edgar F. Andersen, formerly with the Golden Queen Mining Co., is now working for the Calaveras Cement Co., San Andreas, Calif.

Alfred L. Anderson, professor of economic geology at Cornell University, Ithaca, N. Y., is spending his Sabbatical leave of absence in the spring term visiting mining camps in the Rocky Mountain region.

Lloyd E. Antonides receives his mail at 13 Church St., Franklin, N. J. He is surveyor for the New Jersey Zinc Co.

Florentino B. Baca has been plant manager of the Hardsocg Mfg. Co., manufacturers of power driven rotary drilling equipment and miners tools and supplies, a subsidiary of the Cardox Corp. of Chicago, since November, 1947. He lives at 718 W. 4th, Ottuma, Iowa.



Wayne O. Axtell

Wayne O. Axtell, Colonel in the Corps of Engineers, has retired from the Army after a final tour of duty in the Pacific. He is now located as an engineer in the office, Chief of Engineers, Washington, D. C.

W. R. Allen

W. R. Allen is chairman of the board of directors of the Bostana Mines Co. and consultant for Elkhorn Beaverhead Mines Co. He has on the press, ready for distribution, a story of western development and particularly early day mining history in Montana with a backdrop of national events and personalities.

Howland Bancroft, mining consultant, of New York, who has spent the past eighteen months on professional work in South and South West Africa with headquarters in Tsumeb, returned to the States early in March. He will be engaged in an investigation in this country for the next few months, following which he will return to South Africa about mid-year, with headquarters in Johannesburg.

Robert W. Barnes can be reached at 506 Nancy St., Charleston, W. Va. He is employed by the Warner Collieries of Mammoth, W. Va.

Henry E. Bartony, Box 231, Nellis, W. Va., is employed in the engineering department of the Armco Steel Corp.

Andre C. Beguin, who had been a student at the University of British Columbia, is mill engineer for Torbrit Silver Mines, Ltd., Alice Arm, B. C.

Charles H. Behre, Jr., vice-president of Behre Dolbear and Co., New York City, left the States recently for Burma. The Company has been appointed general consultants and technical advisers on minerals for the Burmese Government. Dr. Behre will make his headquarters at Rangoon and prepare recommendations outlining the scope of industrial and mining rehabilitation.

John R. Bogert is employed as a field geologist by the Bethlehem Steel Co., and is addressed in care of W. A. Rankin, construction superintendent, Iron Mines Co. of Venezuela, San Felix, Est. Bolivar, Venezuela.

John P. Bowman is employed by the Foster Wheeler Corp., Carteret, N. J., as a service engineer.

W. A. Broughton is head of the geology department at the Wisconsin Institute of Technology, Platteville, Wis. His address is 225 Bradford, Platteville.

Donald M. Brown is working with the U. S. Geological Survey, estimating coal reserves. His address is 19th and F Sts., FWA Bldg., Washington 25.

Frank A. Burns, who was a student at Lehigh University, is working for the Bethlehem Collieries Corp., Johnstown, Pa., as a junior engineer. His mailing address is Box 62, Ellsworth, Pa.

John L. Beach is chief engineer-geologist in charge of exploration for Rhodesia Copper Ventures Ltd., P. O. Sinoia, S. Rhodesia.

E. L. Beck and his associates have taken over the operation of the Perch hydraulic mine at Orleans, Calif.

Edward J. Bottomley is superintendent of the Sunlight Coal Co., Boonville, Ind. He was with the Tecumseh Coal Corp.

Harold L. Brandt has taken the post of assistant engineer with the Pend Oreille Mines and Metals Co., Metaline Falls, Wash. He had worked in Chihuahua, Mexico, for the American Smelting and Refining Co.

Willis F. Bronkie is vice-president and secretary of the Rising & Nelson Slate Co., West Pawlet, Vt. He has been sales engineer for the Victaulic Co. of America.

Alan D. Brown, graduated from the University of Minnesota School of Mines last June and is now employed by the Anaconda Copper Mining Co. in Butte, Mont.

David W. Boise, formerly of Hurley, N. Mex., where he was working with the Kennecott Copper Co., now lives at 917 West St., Silver City.

Franklin W. Butterfield has transferred from the University of Nevada to the Placer College, School of Mines, Auburn, Calif. He is employed part time by the Empire Star Mines Co. and receives mail at P. O. Box 817, Grass Valley, Calif.

Sam S. Coldren has resigned from the Acoje Mining Co., Santa Cruz, Zambales, to become manager of the Misamis Chromite Co., Na-awan, Initao, Misamis Oriental, P. I. The Company is operated by International Engineering Co. Warner-Barnes.

Alden P. Colvocoresses writes from Box 537, Superior, Ariz., that he has taken over and is maintaining the files of his late father, **George M. Colvocoresses.** These files contain reports and data on approximately 1000 different mining properties in Arizona and adjacent states.

Annan Cook has given up his post as chief geologist to Frobisher Ltd., in Africa, and has accepted a job in the exploration department of the Kennecott Copper Corp.

Boyd Appointment Confirmed

James Boyd's appointment as director of the Bureau of Mines was confirmed by the Senate on March 22 by a vote of 50 to 11. Here he is sworn in by Chief Clerk Dotson as Secretary of the Interior J. A. Krug looks on. The former dean of the Colorado School of Mines took this post in August, 1947, and received pay for about four months until a short session of Congress adjourned in December of that year without confirming him. John L. Lewis, president of the United Mine Workers, who had been blocking confirmation for more than two years, was mentioned only once in the hour-long debate in the Senate and the coal mining stoppage called by Mr. Lewis, partially in protest against Dr. Boyd's appointment, was not mentioned at all.

Ronald Crawford lives at Apt. D., 2509 Park Lane Court S., Mountain Brook, Ala., while he works for the Equipment Service Co., Birmingham, as a sales engineer.

W. H. H. Cranmer, president and general manager of the New Park mining Co. of Keetley, Utah, succeeds **James Ivers,** vice-president and general manager of the Silver King Coalition Mines Co., as president of the Utah Mining Association.

L. A. Dahners has traveled from Anchorage, Alaska, to Skouriotissa, Nicosia, Cyprus, and can be reached there in care of the Cyprus Mines Corp.

James R. Diehl is now employed in the technical department of the engineering and construction division of the Koppers Co. at Pittsburgh. His home is at 409 N. Neville St., Pittsburgh 13.

Ira F. Davis, who is a consulting mining engineer, is now living on Meadville Dr., in Onancock, Virginia.

Byron M. Emery recently graduated from the Pennsylvania State College with a B.S. degree in mining engineering and is employed by the Atlas Powder Co., Wilmington 99, Del., as a technical representative.

John W. England is assistant geologist for the Colorado Fuel and Iron Corp., Pueblo, Colo. His address in Pueblo is Apt. 604-K Air Base.

Harry J. Evans, mining engineer of the Pierce Management staff in Scranton, Pa., left for Korea on March 9 to study the economic potentialities of four coal fields in southern Korea.

A. L. Fairley, Jr., has been made assistant to the president of the Snyder Mining Co. which operates three iron mines on the Mesabi range of Minnesota.

John H. Ffolliott, formerly with the Tennessee Copper Co., is now with the Miami Copper Co., Rm. 1824, 61 Broadway, New York City 6.

John W. Foreman is working for the Monroe Coal Mining Co., Revloc, Pa., as a junior mining engineer.

Edward S. Frohling, after graduating from MIT, worked for a brief period as research engineer for the Division of Industrial Co-operation there. He is now employed by the Climax Molybdenum Co. as a metallurgical testing engineer.

Raymond B. Gallant is now with E. I. du Pont de Nemours & Co. in the explosives sales division. He represents the Company out of the Denver, Colo., office and covers northeast Wyoming and central Montana.

Conrad I. Gardner has gone to Potosi, Bolivia, as engineer for Cia. Minera Unificada del Cerro de Potosi, Casillas 30 y 52.

P. W. Gifford, Jr., who had been general mine foreman for the Lone Star Steel Co., is now superintendent of the slag crusher of Gifford-Hill & Co., Daingerfield, Texas.

B. E. Grant, since 1944 general superintendent of the U. S. and Lark mine of the U. S. Smelting Refining and Mining Co., has been promoted to assistant to the manager of Western mines succeeding **A. G. Kirkland** who became assistant manager of Western mines on Jan. 1. **M. M. DuBois** has been made general superintendent of the U. S. and Lark mine and **Harold H. Wells**, former assistant general mine foreman of the U. S. section, has become assistant superintendent of the Lark section.

Allen D. Gray, Jr., is taking the training program of the Rochester & Pittsburgh Coal Co., Indiana, Pa. His address is 1058 Church St., Indiana.

William A. Griffith and **William A. Griffith** were mixed up in a personal item in the March issue. The former is an instructor at MIT, with an address at 81 Marion St., Brookline, Mass., while the latter is a student at the University of Idaho, Moscow, according to our records. We apologize to the Mr. Griffiths and hope our error has caused them no inconvenience.

F. W. Goddard has been transferred by the AS&R Co. from their Avalos mill unit at Chihuahua to their Parral unit at Parral, Chih., Mexico, in the same post of assistant mill superintendent. The Parral mill produces concentrates of lead, zinc, and copper, milling 1500 tons a day.

Mostyn G. Grant is working for the Coronado Copper and Zinc Co., Los Angeles. His home is at 2031 Pelham Ave., West Los Angeles.

Harry G. Grigsby, former Missouri School of Mines student, is working for the Idarado Mining Co. at Ouray, Colo.

Ivan D. Hagar retired from the Titanium Division of the National Lead Co. last May and moved to R. F. D. 2, Middlebury, Vt. He is retained by National Lead as a consultant.

D. F. Hewitt has left the University of Wisconsin and joined the Ontario Department of Mines staff, Parliament Bldg., Toronto 2, Ont.

Arthur Horen, formerly assistant geologist for the Lone Star Steel Co., is now pursuing graduate study in geology at Harvard. His new address is 27 Maple Ave., Cambridge 38, Mass.

Roy Hatch, labor relations director at the Utah Copper Division of the Kennecott Copper Corp., has been advanced to assistant to the general manager with jurisdiction over all employe and public relations. **L. F. Pett**, assistant mine superintendent, has been made mine superintendent, and **J. C. Landenberger, Jr.**, formerly general mill foreman, replaces Mr. Hatch as director of labor relations.

George Deike and Eugene Jones

Eugene H. Jones, majoring in coal mining engineering at the University of Pittsburgh, received the Old Timers Club award from **George H. Deike**, president of Mines Safety Appliances Co. The Old Timers Club, a social organization of leading coal mining executives, recently decided to give prize awards to outstanding seniors majoring in coal mining engineering at several schools of mines. On Feb. 10 Mr. Deike awarded a gold watch to Mr. Jones, whom a committee had decided upon as outstanding in scholarship, character, and promise. The watch was engraved "Old Timers Club Award to Outstanding Senior Student, Eugene H. Jones, University of Pittsburgh, Class of 1949, Coal Mining Engineering."

F. S. McNicholas and Mrs. McNicholas

F. S. McNicholas returned to Denver the first of April following a month of consulting work on block caving methods at the Mufulira Copper Mines property in Northern Rhodesia. He was accompanied by Mrs. McNicholas.

A. L. Hayes, former superintendent of the Empire Zinc Co. at Hanover, N. Mex., has been transferred to the New York office of the New Jersey Zinc Co., where he will assist the general manager of mines, **S. S. Huyett** has been appointed superintendent of the Empire Zinc Co. at Hanover.

Ira K. Hearn, Jr., who was formerly works industrial engineer of ore mines and quarries for the Tennessee Coal, Iron and Railroad Co., Bessemer, Ala., has recently accepted the post of assistant to the president of the Quebec Iron and Titanium Corp., a subsidiary of Kennecott Copper. His office is at 120 Broadway and he is making his home at the Park Garden Apartments, 134-42 Franklin St., Morristown, N. J.

Arthur S. Hecht, consulting engineer of San Francisco, is now an associate of Behre Dolbear and Co., consulting mining engineers and geologists, 11 Broadway, New York City 4. Mr. Hecht recently returned from Korea and completed an assignment for the Civil Affairs Section of the Army and the ECA for Korea as a consultant, in the United States, on a research project for tungsten ore beneficiation.

Charles T. Holland has joined the staff of the mining engineering department of the Virginia Polytechnic Institute. He had been professor of mining engineering at West Virginia University. Mr. Holland succeeds **L. I. Cothern** who is head of the mining engineering department at Ohio State University.

Fred H. Howell is employed as a mining engineer and geologist with the Federal Mining and Smelting Co. at the Page mine, Page, Idaho.

Charles O. Hower is addressed at Emmett, Idaho, and works as metallurgist for the Calera Mining Co. at Forney.

Charles D. Hoyt graduated from Penn State on Jan. 31 and is now employed by the Westmoreland Mining Co. His new mailing address is 143 S. Spring St., Blairsville, Pa.

Lemuel B. Hunter has been made manager of the raw materials department of the Inland Steel Co., Chicago.

Nick Hurley has resigned his post with Cie. Aramayo de Mines en Bolivie at La Paz and can now be reached at 1510 Mathews, Fort Collins, Colo.

Robert H. Inman has taken the job of assistant engineer with the United Electric Coal Co., Chicago. Mail reaches him at 403 N. First St., Canton, Ill.

John A. Johnson is acting supervisor at the Duluth office of the Bureau of Mines.

W. Bruce Johnson is employed as a coastal analyst for the Navy Department. His address is Rm. 3A-538, Pentagon Bldg., Washington 25, D. C.

Russell C. Johnson has changed his address to in care of the Northern Peru Mining and Smelting Co., Casilla 219, Lima, Peru. He had been with Cia. Minera Asarco.

Theodore L. Johnston has resigned as metallurgist for the Bureau of Mines to do consulting work with headquarters at Hamilton, Mont.

Frederick C. Kruger, assistant chief geologist of the Cerro de Pasco Copper Corp., is on leave of absence and will be at Northwestern University, Evanston, Ill., as lecturer in geology during the winter and spring quarters.

Thomas A. King, Box 651, Clarksville, Pa., is a student engineer with the Westmoreland Mining Co., Blairsville, Pa.

Charles P. Knaebel and a partner have taken a lease from the U. S. Smelting Refining and Mining Co. on its Shingle Canyon mine, near Fierro, N. Mex. The operations consists of small scale production of zinc-lead ore.

Edward H. Kraus has been, since February, 1945, on the retired list of the University of Michigan. However, this does not mean that he is not pursuing actively mineralogical and gemological affairs. In fact, with his colleague, C. B. Slawson, they were able to bring out the fifth edition of Gems and Gem Materials in December, 1947. At present, with W. F. Hunt and L. S. Ramsdell, he is at work revising the Mineralogy and hopes to bring out the fourth edition within a year or two.

H. M. Lavender has been made a member of the board of directors of the Phelps Dodge Corp. He is vice-president and general manager of Phelps Dodge in charge of all western operations of the Corporation.

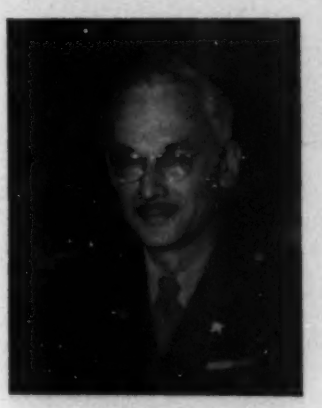
John W. Lowry is process metallurgist in the division of metallurgical research of the Permanente Metals Corp., Spokane, Wash. Mail reaches him at E. 10918 Main, Opportunity, Wash.

John R. LeGrand is working for the Atlantic Coast Line Railroad, Wilmington, N. C., as an industrial geologist.

Robert T. Macaul is working in the rock drill department of the Ingersoll-Rand Co., 11 Broadway, New York City 4.

Edward Marks, while working on his Master's degree, is a student assistant in the department of geology at the University of Texas, Austin.

Victor R. Martin lives at 642 S. Gilpin St., Denver, and during working hours is field engineer for the National Fuse and Powder Co. He moved to Denver from Butte, where he was underground engineer for the Anaconda Copper Mining Co.



Charles Gill Morgan

Charles Gill Morgan returned to Dallas, Texas, in January and has offices in the Tower Petroleum Bldg., specializing in petroleum geology and research in seismology and glaciology. After graduation from SMU, he served with the Geophysical Research Corp. and the Seismograph Service Corp., spent two years in graduate study at Harvard, and then was off to the Antarctic with Admiral Byrd as chief geologist on his second expedition. In 1936 he became associated with Herbert Hoover, Jr., as vice-president of the United Geophysical Co. in California. Called to active duty in Washington as a Captain in the Air Corps in 1941, Colonel Morgan was successively in charge of Latin American intelligence, European targets, and finally the Operational Intelligence Division for both theaters of war. As the war neared its close in Europe, he was relieved from his assignment by the War Department in Washington to serve on the USAF Evaluation Board as director of tactical air operations in Europe. He returned to inactive duty in March, 1946, and has been engaged in independent research and as consultant in Boston and New York since that time.

John F. Marley has been assistant mine superintendent with the Gouverneur Talc Co. at Balmat, N. Y., since last October. His address is 179 Rock Island St., Gouverneur, N. Y.

Richard R. Matthew, county surveyor and mining engineer for the U. S. Grant Mining Co., who lives in Virginia City, Mont., is the president of the Madison County Mining Association.

Arne A. Mattila has been appointed mining engineer of the mining branch, conservation division, U. S. Geological Survey, and will assist with the supervision of mining operations on leased government land in the Billings, Mont., district. Mr. Mattila is a graduate of the Montana School of Mines, class of 1936. His mining experience includes about seven years with the Anaconda Copper Mining Co. and three years as mining engineer with the Republic Coal Co. of Roundup, Mont.

Walter L. Maxson, vice-president of the Oliver Iron Mining Co., Duluth, Minn., has been appointed to the Atomic Energy Commission's Advisory Committee on Raw Materials. Mr. Maxson has been an officer of the Oliver company since 1944. Prior to that he was sales manager and chief engineer of the mining division of the Allis-Chalmers Mfg. Co. for seventeen years. He has also served as associate professor of metallurgy at the Colorado School of Mines, and has been connected with several mining companies in Colorado, Arizona, and Australia.

John W. Mrock transferred on Jan. 28 from the Bureau of Reclamation, Coachella, Calif., to the Navy Department, and is employed at present as a laboratory technician at the Naval Air Missile Testing Center at Point Mugu, Calif. His new mailing address is 245 W. 1st St., Oxnard, Calif.

Harvey S. Mudd, president and managing director of Cyprus Mines Corp., officer of several West Coast business organizations, and past president of the Institute, was given the Egleston medal, awarded annually by the Columbia University Engineering School Alumni Association for distinguished engineering achievement, on April 28. Mr. Mudd's principal professional activity for many years has been the development and management of important copper mines in the Island of Cyprus. From 1914 to 1926 he devoted his energies to these and other mining properties. During the many years of his connection with Cyprus Mines, Mr. Mudd has solved numerous complex mining and metallurgical problems involving mine ventilation and safety, fire hazards, and production.

Henry D. Mumper is engineer in the steam and combustion department of the Bethlehem Steel Corp., Johnstown, Pa. His mail goes to 711 Graham Ave., Windber, Pa.

John C. Murray, who has been at the Pittsburgh works of the Jones & Laughlin Steel Corp., has joined the staff of the Republic Steel Corp. at Youngstown, Ohio.

Dwight L. Myers recently accepted

a post under the city engineer in Spokane, Wash., as construction engineer. His work will be wholly devoted to a $3,500,000 construction job of which about ten per cent has already been awarded to contract.

W. Clark Mason has resigned as metallurgist for the Inspiration Consolidated Copper Co. and has gone to San Francisco as metallurgist for the Merrill Co. His new address is Hill Castle Apt., 1431 Jackson St., Oakland 12, Calif.

R. K. Matheson is now reached at the Coronado Copper and Zinc Co., Bella Vista, Calif.

Donald H. McLaughlin has been appointed chairman of the National Committee of sponsors of the Harvard Foundation for Advanced Study and Research.

Herbert H. Mellus is pit engineer of the new open pit project of the Inspiration Consolidated Copper Co., Inspiration, Ariz.

James J. Merle has changed his address to the Fairview Collieries Corp., Box 86, Danville, Ill. He was chief chemist for the Ayrshire Patoka Collieries Corp.

Henning C. L. Meyer, who used to be with the New Jersey Zinc Co., has moved to 1507 S. 78th St., West Allis, Wis. He is working for the Allis-Chalmers Mfg. Co.

Gilbert Monroe graduated in mining engineering from the University of Alaska last May and now works as a junior engineer with an aircraft company. His address is Apt. 12, Darrell Hotel, 703 8th Ave., Seattle, Wash.

Perry F. Narten, after graduating from Washington University, St. Louis, Mo., went to work for the U. S. Geological Survey, Washington 25, D. C.

M. J. O'Shaughnessy has become project superintendent of Allard Lake (Quebec) Mines Ltd., Havre St. Pierre, P. Q. He was with the Alger Gold Mines.

W. P. Putnam has retired from active business and is spending his winters at 1001 Hamlin Ave., Orlando, Fla., where he is enjoying a change from northern winters.

Edwin H. Oshier is field superintendent for the Round Mountain Gold Dredging Corp., Round Mountain, Nev. He had been with the Golden Queen Mining Co., Mojave, Calif.

W. C. Page became assistant general manager of Western operations of the U. S. Smelting Refining and Mining Co. on March 1. In addition to his general duties, Mr. Page will continue to have direct supervision over the Midvale plant operations and the refining operations of the Company.

K. Peters

K. Peters, formerly manager in charge of the mining and metallurgical operations of the Mahad Dahab property of the Saudi Arabian Mining Syndicate, has been appointed consultant on mining affairs to the Kingdom of Saudi Arabia. Mr. Peters will make his headquarters in Jedda, Saudi Arabia.

Louis A. Panek is associated with the Bureau of Mines at College Park, Md., doing research in connection with roof control and the use of suspension supports. He is visiting properties where suspension supports are being introduced in order to keep informed of the problems being encountered in the field.

Everett M. Paris is employed as mine superintendent with the U. S. Vanadium Corp. at Uravan, Colo.

Roy I. Petersen is assistant superintendent of the shaft sinking division of the Bethlehem Collieries Corp., and is addressed at R. D. 1, Bentleyville, Pa.

Alan P. Ploesser has gone to Baguio, Philippine Islands, to work for the Benguet Consolidated Mining Co.

O. Edward Pothier is a mining engineer in the exploration department of the Simplot Fertilizer Co., Pocatello, Idaho. He receives mail at Rt. 7, Boise, Idaho.

Emmett S. Pugh, president of the Raleigh Smokeless Coal Co. until 1946 when it was sold to the Blackstone Coal Co., has announced the organization on Feb. 1 of a new operating sales company called the Raven Pocahontas Co. The new company will be owned entirely by the producing companies represented, the officers, and the employes. The four operating companies concerned at present are Raven Coals, Inc., the Raven Peerless Co., Raven Red Ash Coal Co., and an affiliate, and the Red Ash Mining Co., which are producing about 2500 tons per day of mid-volatile coal.

Richard Quirk has been appointed assistant superintendent of the Morococha department of the Cerro de Pasco Copper Corp., Morococha, Peru. He was formerly general mine foreman there.

Alfred L. Ransome has been transferred from his former post as supervising engineer of the San Francisco office of the metal economics branch of the Bureau of Mines to one of similar capacity with the newly established metal economics branch office in Juneau, Alaska. On Dec. 5, a little "sourdough," David Miles, 7 lb. 4 oz., was added to the Ransome family roster by way of St. Anns Hospital, Juneau.

Avery H. Reed, Jr., is employed as a mining engineer with the Bureau of Mines, Box L, University, Ala. He had been general superintendent of the Gilbert & Hageman Co., Lexington, Ky.

Gilbert R. Richardson has gone "down under" to Sydney, N. S. W., where he is reached at the Eveready (Australia) Pty. Ltd., P. O. Box 37, Mascot.

A. E. Roberts, since he was graduated from the College of Mines at the University of Arizona last May, has been employed on the engineering staff of the Magma Copper Co. at Superior, Ariz.

Ernest H. Rose, now doing research and development work for the Tennessee Coal, Iron and Railroad Co., has been appointed to the Committee on Raw Materials of the Atomic Energy Commission. Mr. Rose, whose work with TCI is directed toward the exploitation of Alabama's silicious iron ores, was mill superintendent for the International Nickel Co. of Canada at Copper Ciff, Ont., for many years.

Clyde R. Russell, who was mine superintendent of the Tonopah Belmont Consolidated Mining Co., Tonopah, Nev., has gone to Oruro, Bolivia, where he is addressed at Casilla No. 154.

Margaret A. Ryan went to work for the Anaconda Copper Mining Co. in January as a technical chemist at the Washoe smelter, Anaconda, Mont.

V. P. Sokoloff is a soil scientist and geochemist in the geochemical prospecting unit of the U. S. Geological Survey, Denver Federal Center, Denver 14, Colo.

Alex E. Stutter, secretary of the Committee on Membership, AIME, and his wife Frances, are the proud parents

of George Alexander who was born March 18 at the Bethany Deaconess Hospital, Brooklyn, N. Y.

Robert A. Stauffer has been elected vice-president and director of research of the National Research Corp., Cambridge, Mass. Mr. Stauffer, a Harvard graduate, has been associated with the company since 1942.

J. S. Sumner is engaged at present in geophysical prospecting on the Marquette range. He is addressed in care of the geological department of the Cleveland-Cliffs Iron Co., Ishpeming, Mich.

Charles Will Wright has been acting as consulting engineer for ECA on a part-time basis, but his permanent connection continues as consultant to Westinghouse Electric International, Rm. 1810, 40 Wall St., New York City. He spends a part of each week in Washington, where his home address is 2540 Massachusetts Ave., Washington 8, D. C.

William E. Wright has changed his professional address from Pennsylvania State College to commodity specialist, U. S. Tariff Commission, Washington 25, D. C.

George G. Yeager, with the Aluminum Co. of America, has been transferred to the company's purchasing department in Pittsburgh. His address is 3229 Circle Drive, Pittsburgh 27, Pa.

• In the Metals Divisions

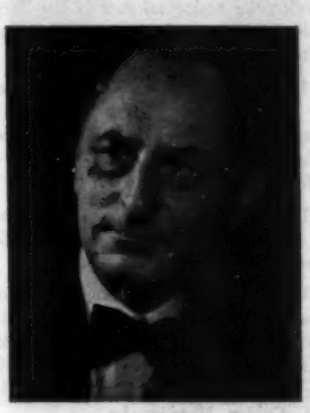
Elbert E. Alpers works for the General Motors Corp. central foundry division as a metallurgist. Mail reaches him at Apt. 2, 1201½ E. Main St., Danville, Ill.

J. R. Brady has been made supervisor of the research and testing department of the Wisconsin Steel Works, Chicago.

M. H. Caron, of Delft, and **Herman Ebbinge,** of Den Haag, Netherlands, have recently been in the United States and Canada on professional work. Professor Caron reports that the university at Delft is in serious need of a copy of AIME Transactions volume 121, on lead and zinc, now out of print. If a member has a copy he can spare, he would like to be advised.

E. Corbin Chapman has been appointed chief metallurgist of Combustion Engineering-Superheater, Inc., and will continue to make his headquarters in Chattanooga, Tenn. Mr. Chapman has been employed by Combustion since his graduation from Cornell in 1928 and is the author of numerous articles and papers on welding and metallurgical subjects. During the second World War he served as supervisor of the National Defense Research Council project on development of electrodes for welding armor plate.

Herbert J. Cooper is working for the Cooper Alloy Foundry Co. as an engineer on research and development. He lives at 336 Harding Dr., South Orange, N. J.



Otto Barth

Otto Barth on Feb. 25 was named professor of nonferrous metallurgy at the Royal Institute of Technology in Stockholm.

Lee H. DeWald is metallurgical engineer for the National Cylinder Gas Co., manufacturers of industrial gases and welding equipment, Chicago. He receives mail at 828 Main St., Aurora, Ill.

Delmar W. Dow has the job of metallurgical engineer with the Permanente Metals Corp. at the Mead works, Spokane, Wash. His address in Spokane is 10014 Whittier St., Rt. 7.

Norman F. Dufty is now employed as technical assistant in the open hearth department of the Australian Iron and Steel Co., G.P.O. Wollongong, N. S. W. Australia.

Clarence W. Fabel is no longer employed by Remington Rand, Inc.; his present post is metallurgist with the Simonds Saw and Steel Co., Lockport, N. Y.

John H. Fuqua graduated from the Missouri School of Mines in January and has taken a job with the American Steel Foundries in the research laboratory at their Indiana Harbor plant. His address is 8020 S. Paulina St., Chicago.

William K. Heid is taking the supervisory training program at the Pontiac motor division of the General Motors Corp. He lives at 89 S. Roselawn Drive, Pontiac 20, Mich.

K. H. Heino is working at Noranda, Que., as technical assistant for Noranda Mines Ltd.

George O. Hiers works in the research laboratories of the National Lead Co., 105 York St., Brooklyn 1, N. Y.

G. W. Higgins works for the Wehr Steel Co. at West Allis, Wis. His mail goes to 1743 S. 58th St., West Allis.

Erle J. Hubbard has resigned from his post as foundry superintendent in the piston ring division of the Koppers Co. and accepted the post of foundry manager of the Janney Cylinder Co., 7421 State Rd., Philadelphia, Pa.

Raymond A. Humphreys is metallurgical inspector and secretary of the materials review board of the Chase Aircraft Co., West Trenton, N. J.

William A. Johnson, formerly at Oak Ridge, Tenn., at the Clinton laboratory of the Monsanto Chemical Co., has gone to Pittsburgh, Pa., to work with the atomic power division of the Westinghouse Electric Corp.

F. G. Kerry, who lives at 227 Glendale Rd., Scarsdale, N. Y., is manager of the engineering development department of Spaco Inc. (Air Liquide), oxygen producers and plant manufacturers, 529 Chrysler Bldg., New York City 17.

Charles H. T. Wilkins

Charles H. T. Wilkins, formerly metallurgist with the Copperweld Steel Co., heads the National-Standard Company's industrial fellowship at Mellon Institute in Pittsburgh. The Niles, Mich., company established the fellowship to investigate, in a long-range program, major problems related to the technology of fine wire products, such as tire bead wire, strand for heavy duty tire casings, music wire, and aircraft and textile wires. Also to be studied are problems related to flat strip for use in such products as piston rings, razor

blades, clock-and-watch springs, pen points, and umbrella ribs. Mr. Wilkins was graduated from VMI and subsequently pursued advanced work in metallurgy at the University of Pittsburgh, receiving his M.S. degree there in 1946.

C. H. Lenhart has resigned as general superintendent of the steel plant of the Iron and Steel Division of the Kaiser Co., Fontana, Calif., and is replaced by **George B. McMeans.**

Arthur M. Monson has resigned from the Stearns-Roger Mfg. Co. to enter the realty business as salesman for Foster & Barnard, Inc., Chamber of Commerce Bldg., Denver.

William R. Opie

William R. Opie, a research assistant in metallurgy at MIT, received a degree of Doctor of Science in metallurgy in February. He is now employed as a research metallurgist by the American Smelting and Refining Co. in their central research department at Barber, N. J. His home address is 99 3rd St., Raritan Township, Fords, N. J.

• In Petroleum Circles

Paul T. Bail is working for the Bureau of Mines at Franklin, Pa. He used to be with the Stanolind Oil and Gas Co. in Wink, Texas.

Robert E. Bennett has joined the staff of the California Co. as a petroleum engineer at Harvey, La.

Paul Biggs resigned his job with the Stanolind Oil and Gas Co. at Big Lake, Texas, in February and is now employed by the Bureau of Mines at the petroleum and oil shale experiment station, Laramie, Wyo., as a petroleum engineer.

Guy Borden, Jr., assistant professor of petroleum engineering at Louisiana State University, has joined the production research department of the Stanolind Oil and Gas Co. at Tulsa, Okla.

Pete W. Cawthon, Jr., is completing a training program in the production department of the Phillips Petroleum Co. He finished work on a master of engineering degree, petroleum, at the University of Oklahoma last September. His degree will be granted in June.

Courtney E. Cleveland, after spending a number of years as geologist and exploration engineer with Bralorne Mines Ltd. of Vancouver, B. C., is now joining the geological staff of the Barnsdale Oil Co., 735 8th Ave. W., Calgary, Alta.

Robert R. Cocke, III, is a student at the University of Texas as well as part time engineer for the Railroad Commission of Texas. He lives in Apt. 1, 1807 Brazos, Austin, Texas.

Lynn R. Cook, Jr., can be reached at the Richmond Exploration Co., Apartado 93, Maracaibo, Venezuela.

William R. Corby is working for the Spartan Drilling Co. in the Golden Meadow field. At present he is doing work in both the production and drilling departments. His address is Box 506, Golden Meadow, La.

William J. Cox, as a petroleum geologist with the Creole Petroleum Corp., has gone to Barcelona, Anzoategui, Venezuela.

Jeral J. Crowder resigned as petroleum engineer from the Gulf Oil Corp. the first of the year to assume duties with the Quintana Petroleum Corp. as petroleum engineer for their producing and drilling department at Houston, Texas. Mr. Crowder attended Texas A&M College, studying petroleum engineering, and later he received a B.S. degree in mechanical engineering from the University of Houston.

Charles E. Davis, upon graduation from SMU in Dallas last May with a B. S. in geology, accepted a post with the Gulf Oil Corp. and was subsequently assigned to work in the N. Ward-Estes field of Ward and Winkler Counties, Texas, as a field geologist.

John O. Davis graduated from the University of Texas with a degree in petroleum engineering in February 1948 and since that time has been employed by the Jergins Oil Co. at Victoria, Texas, as production foreman.

Jack M. Denson graduated from the University of Texas last June with a B. S. degree in petroleum engineering and is now working for The Texas Co. as a petroleum engineer trainee. His address is Box 82, Buckeye, N. Mex.

William C. Dinger, formerly with the Houston Oil Co. of Texas, can be reached at Rock Springs, Wyo., where he is associated with the Mountain Fuel Supply Co.

John R. Evans is undergoing a one year training program as junior petroleum engineer for the Creole Petroleum Co., New York City, but receives mail in care of R. N. Dyer, Humble Oil and Refining Co., Houston, Texas.

Gearld I. Freeze, former instructor in the department of petroleum engineering at the University of Kansas, is now in the production department of the Phillips Petroleum Co., Box 1605, Hobbs, N. Mex.

Ionel I. Gardescu has been promoted to manager of the gas reserve department of the Transcontinental Gas Pipe Line Corp., Oil and Gas Bldg., Houston 2, Texas.

John T. Gary, with the Continental Oil Co., was transferred on Jan. 1 from district petroleum engineer at Wichita Falls, Texas, to production engineer in the general office at Ponca City, Okla.

Benjamin F. Hake can be reached at the geological department of the Gulf Oil Corp., Box 1166, Pittsburgh 30, Pa.

A. S. Hawley resigned in January from the Schlumberger Well Surveying Corp. and accepted the post of geologist with the Union Oil Co. in Bakersfield.

Jack P. Hays is production superintendent for the Intex Oil Co., Dallas, Texas, but his mail goes to 64 Bacon Bldg., Abilene, Texas.

Richard V. Hughes, formerly with the Penn Grade Crude Oil Assoc., has gone to Stanford, Calif., as geologist with the Stanford Research Institute.

Joe B. Justus graduated from Louisiana State and is working for the California Co., Ruston, La., as a production engineer.

James E. Keller has gone to Caracas, Venezuela, to work for the Creole Petroleum Corp. He is addressed there at Apartado 889.

Leslie A. Leuzinger is field engineer at Rangely, Colo., for the Union Pacific Railroad Co., oil development.

Robert L. Lindauer, Jr., receives mail at P. O. Box 357, Katy, Texas. He is a junior gas engineer with the Humble Oil and Refining Co.

Donald P. McCarthy, who was a student at the Montana School of Mines, is working in the gological department of the Sinclair Prairie Oil Co., Albuquerque, N. Mex.

John M. McLain is junior exploita-

tion engineer with the Shell Oil Co., Houston, Texas, but gets his mail at 823 Main St., Hattiesburg, Miss.

Richard H. Zinszer can now be reached in care of the research department of the Union Oil Co. of California, Wilmington, Calif.

Obituaries

Charles E. LeNeve Arnold

AN APPRECIATION BY JAMES L. HEAD

"Charlie Arnold died yesterday." Seldom does such sad news spread as rapidly as it did on Monday morning, Jan. 24, throughout the six floors of 25 Broadway, New York City, which house the vast New York organization of Anaconda. From top brass to office boy, from veteran to newest comer, all felt a distinct and unusual personal loss for he enjoyed the widest personal acquaintanceship in the entire organization. When the news of his passing was communicated to Inspiration, Potrerillos, Chuquicamata and Cananea, to each of which he had made definite contribution, to the Mining Club and to Institute Headquarters, it evoked the same reaction and added additional evidence of the particular esteem in which he was held by everyone who knew him. He was always the considerate, discerning, courteous, gentlemanly and unfailing friend of all. It is to such rare individuals that great organizations really owe that intangible thing, esprit de corps.

"None knew thee but to love thee,
Nor named thee but to praise"

For the record, Charles Everard LeNeve Arnold was born in Auckland, New Zealand, on Sept. 13, 1883, where he is survived by a father and brother. He attended Auckland University from March to November, 1901. His choice of a career in the mineral industry must have been an early one, for between 1900 and 1902 he was a bullion melter and assayer at Waihi, New Zealand. I do not know why he came to the States, but he did so in 1902, matriculating at the University of California, from which he was graduated in 1906. Here he was a schoolmate of Erle V. Daveler, James S. Wroth, John Tyssowski, and the late Spencer Browne. One of his favorite tales—and he was a raconteur par excellence—was of his first day in this country when he was initiated into American barbershop practice—and paid for the "works."

His summer vacations during college followed the traditional pattern of the embryo mining engineer of that day. We have such unglamorous items as machine hand, Union Iron Works, San Francisco; miner, Keystone Gold Mine, Amador City, Calif.; cyanide hand, North Star Corp., Grass Valley; sampler, Fresno Copper Corp., Gordon, Calif.; and draftsman at Ely for Nevada Consolidated. Following graduation, he was from 1905 to 1911 construction and mine engineer for the Girous Consolidated Mines Co. at Kimberley, Nev., and I think it was here that he met the future Mrs. Arnold, Miss Genevieve Mills.

Moving on to Inspiration, the newest addition to the porphyry copper group, he was mine engineer there from 1911 to

1918 and had much to do with the sound planning which was the basis for the success of that operation. In 1918, he was called to New York City and it is not surprising that with this background and wealth of experience he was designated to function in a similar capacity in the planning and development of Anaconda's newest venture, the great Andes Copper Mining Company's mine at Potrerillos, Chile. In 1924 he became assistant to William Wraith, vice-president, Andes Copper Mining Co., Greene Cananea Copper Co., and Inspiration Consolidated Copper Co., and he served in this capacity until Mr. Wraith's retirement at the end of 1945. Subsequently he continued in close touch with the operations of these companies.

All of which adds up to the fact that Arnold was an exceedingly capable engineer. So useful, dependable, and conscientious was he in the ever essential "information please" capacity, that he was never quite able to shake off the shackles and inhibitions which so often prevent a fine engineer from achieving top executive rank.

He became a member of AIME in 1906 and was one of headquarters' dependables. He was particularly active in the New York Section, having served as secretary, 1934, treasurer 1935-37, vice-chairman, 1938 and chairman 1939. Always intimately connected with the Annual Meetings of the Institute in New York City, his designation as chairman of any committee, annual banquet, informal dance, reception, etc., insured the success of that particular function. He had looked forward to attending the recent Annual Meeting in San Francisco. At the time of the organization of the Mining Club in New York City in 1930, he was invited to become a charter member and he was elected to membership in the Mining and Metallurgical Society of America in 1939.

The fact that he had suffered an initial heart attack on Labor Day, 1940, did not deter him from carrying on, and although he was possibly living on borrowed time, he continued to be the genial and unforgettable Charlie Arnold.

D. B. McAllister

All who have regularly attended the Annual and Regional meetings of the Institute will be saddened to hear of the death of one of those whose presence has contributed so much to those occasions—D. B. McAllister, of San Luis Potosi, Mexico. "Mac," as he was known to so many friends, and to his wife as well, died on March 28. The last time we saw him was at the stag dinner at the San Francisco meeting, when we sat next to him. At that time he seemed a bit repressed for Mac, but we had no idea this might have been a foreboding. We had exchanged pleasantries at many other meetings, and he was always making a joke of something, or assuming a character that he thought might shock strangers. We are sure that a host of Institute members must have had a cordial invitation to visit at the McAllister home in San Luis Potosi, as we have, and no doubt many have been able to drop off there, as we have not. His good wife was always with him at meetings, endeavoring to keep him straight, as he explained. She will be an especially lonely woman. The Institute has lost not only a competent engineer but an active member and one who, although not on many of its technical programs as an author, helped greatly to make attendance at its meeting a satisfying experience.—*E. H. R.*

Daniel Bruno McAllister (Member 1920), was a native Bostonian, born in 1881, and a Harvard graduate, class of 1905. The year after graduation, he worked as a surveyor for the Pennsylvania tunnels in New York City, and for the next three years held engineering positions in West Virginia, Michigan and New York. In 1910 he became an engineer for the Cia. Metalurgical Mexicana, beginning a lifelong association with Mexican mining which was interrupted only by four years in New Mexico and two years with New York State's Public Service Commission. In 1925 he leased the El Barreno mine in San Luis Potosi, and for the past twenty-three years had resided in that city, actively engaged in mining enterprises.

Necrology

Date Elected	*Name*	*Date of Death*
1939	LeGrande D. Barrett	Unknown
1920	Lucius A. Butler	Jan. 23, 1949
1946	Herschel E. Denton	March 30, 1949
1931	Cecil Drake	Jan. 31, 1949
1917	Frederic W. James	Dec. 28, 1948
1920	Daniel B. McAllister	March 28, 1949
1915	Alexander G. McGregor	March 4, 1949
1936	Arthur S. Nichols	Feb. 18, 1949
1916	Chase S. Osborn	April 11, 1949
1948	Thomas M. Robertson	Aug. 16, 1948
1940	William A. Ross	Jan. 30, 1949
1904	David R. Thomas	March 4, 1949

HAROLD E. WILLSON (Member 1916), West Virginia mining engineer who headed his own firm at Oak Hill, is dead. A graduate of the University of Illinois, class of 1916, Mr. Willson worked with various West Virginia coal companies before forming his own engineering organization, the H. E. Willson Engineering Co., in 1918, which he operated until the time of his death.

Proposed for Membership

Total AIME membership on March 31, 1949, was 15,363; in addition 4082 Student Associates were enrolled.

ADMISSIONS COMMITTEE

James L. Head, Chairman; Albert J. Phillips, Vice-Chairman; George B. Corless, T. B. Counselman, Ivan A. Given, George C. Heikes, Richard D. Mollison, and Philip D. Wilson.

Institute members are urged to review this list as soon as the issue is received and immediately to wire the Secretary's office, night message collect, if objection is offered to the admission of any applicant. Details of the objection should follow by air mail. The Institute desires to extend its privileges to every person to whom it can be of service but does not desire to admit persons unless they are qualified.

In the following list C/S means change of status: R, reinstatement; M, Member; J, Junior Member; AM, Associate Member; S, Student Associate; F, Junior Foreign Affiliate.

ALABAMA

Bessemer — SAUNDERS, ARCHIE OLIVER. (AM). Service engineer, Independent Pneumatic Tool Co.

Florence—SHERWIN, RALPH SIDNEY. (R—M). Vice-president in charge of alumina development, Reynolds Metals Co.

ARIZONA

Hayden—TUCK, FRANK JOSEPH. (R—M). Mill superintendent, Kennecott Copper Corp.

Jerome—FULTON, DAVID HOLMES. (C/S—S-J). Stope engineer, Phelps Dodge Corp.

Superior — ANDERSON, RICHARD COLEMAN. (C/S—J-M). Mining engineer, Magma Copper Co. ROBERTS, ALVAN E., JR. (C/S—S-J). Transitman, engineering dept., Magma Copper Co.

ARKANSAS

El Dorado — McDONALD, PAUL CRANFORD. (R,C/S—J-M). Field superintendent, C. H. Murphy & Co.

Little Rock—HESS, ALBERT JOHN. (M). Mining engineer, The Milwhite Co.

CALIFORNIA

Alhambra—NASH, WILLIAM FRANCIS, JR. (M). Staff consultant, C. F. Braun & Co.

Berkeley—PIETROKOWSKY, PAUL. (C/S—S-J). Research metallurgist, University of California. SCHUELER, DORNER TURNER, JR. (C/S—S-J). Chief engineer, Industrial Minerals & Chemical Co.

Buena Park—WRIGHT, CHARLES CATHBERT. (J). Chemist, Oil Well Research, Inc.

Inglewood—GRAVES, DOYLE THEODORE. (J). Subsurface engineer, Union Oil Co. of California.

Long Beach—VAN RIPER, JOHN. (M). Petroleum engineer, Continental Oil Co.

Los Angeles—BOYES, RALPH LEE. (J). Assistant field engineer, Union Oil Co. EVANS, THOMAS O. (M). Mining engineer, Atchison, Topeka & Santa Fe Railway Co. JAKOSKY, JOHN JAY, JR. (C/S—S-J). Engineer, International Geophysics, Inc. MARSHALL, IRA ALLISON, JR. (J). Production equipment engineer, Shell Oil Co.

Ojai — DOIG, KEITH. (J). Junior mechanical engineer, Shell Oil Co.

San Francisco — MORBIO, CARLO SUTRO. (AM). Consultant.

South Gate — LIETZOW, CLYDE HARVEY. (J). Sales engineer, Pelton Water Wheel Co.

South Pasadena—PAUL, WILLIAM GLAE, JR. (J). Representative, Kobe, Inc.

Ventura—WEST, W. FRANK. (C/S—S-J). Petroleum engineer-trainee, Continental Oil Co.

Whittier—FAULL, RICHARD FRANCIS. (M). Manager, La Habra Laboratory, California Research Corp.

Wilmington—FEI, ROBERT FLEMING. (C/S—S-J). Petroleum engineer-trainee, Union Oil Co.

COLORADO

Denver—BOARD, VIRGIL LEE. (M). President, Western Exploration & Management Co. SNEDDEN, HENRY DAVID. (R,C/S—J-M). Metallurgist, Humphreys Investment Co.

Golden — LOEB, MICHEL JEAN. (C/S—S-J). Graduate student, Colorado School of Mines.

Trinidad—DUREN, JACK DANIEL. (C/S—S-J). Junior exploitation engineer, Shell Oil Co.

CONNECTICUT

Manchester—DAY, ROBERT B. (C/S—S-J). Metallurgical engineer, Linde Air Products Co.

New Haven—HIBBARD, WALTER ROLLO, JR. (C/S—J-M). Assistant professor of metallurgy, Yale University.

Ridgefield — MARTIN, MAURICE HENRI. (M). Chief engineer, Schlumberger Well Surveying Corp.

Stratford — CLARK, HOWARD T., JR. (M). Research metallurgist, Remington Arms Co.

Waterbury — DUBPERNELL, GEORGE. (M). Manager, Waterbury laboratories, United Chromium.

DISTRICT OF COLUMBIA

Washington—WARNCKE, RUSSELL GEHRING. (R,C/S—JA-M). Mining engineer, safety branch, Bureau of Mines. WRIGHT, WILLIAM EDWARD. (C/S—S-J). Commodity specialist (ceramics), U. S. Tariff Commission.

GEORGIA

Marietta—WILLINGHAM, CHARLES BERRIEN. (M). Sales engineer, Joy Mfg. Co.

IDAHO

Kellogg — McDONALD, JAMES THOMAS. (C/S—S-J). Surveyor, Bunker Hill & Sullivan Mining & Concentrating Co.

Wallace — NELSON, VERNON JEROME. (AM). Division manager, Coeur d'Alene mining division, Washington Water Power Co.

ILLINOIS

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Weirton — HARRIS, RALPH WILLIAM. (C/S—S-J). Tester, first class, Weirton Steel Co.

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NEW SOUTH WALES

Ashfield — KING, MALCOLM GEORGE. (AM). Research engineer, Australian Blue Asbestos, Ltd.

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Student Associates

Elected March 16, 1949

Louis L. Bergan.....Mont. Sch. Mines
John B. Clark.....Carnegie Inst. Tech.
Henry L. Hurley.....S. Dak. Sch. Mines
Nelson Severinghaus, Jr.....Univ. Ariz.
Ernest Stewart (Rein.).....Univ. Ariz.

Elected April 20, 1949

Alfred Ainsworth, Jr.....Univ Wichita
Harold G. Alford.....Univ. Tulsa
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Emmet H. Baich, Jr.....Univ. Tulsa
Laurence H. Beal.....Univ. Calif.
John T. Berry (Rein.).....Texas A&M
Christy R. Bickford, Jr....Univ. Wichita
George A. Bivens.....Univ. Mich.
Dewey A. Bjork.....Mich. Min. & Tech.
John L. Black.....Otago Univ.
Robert D. Black.....Fenn Coll.
Edwin A. Blackey, Jr.....Univ. N. H.
Carter H. Boswell.....Univ. S. Calif.
Maurice H. Brady.....Univ. Nev.
Leo R. Brammer, Jr.....Univ. Tulsa
Stanley G. Britton.....Univ. Tulsa
Robert G. Broady.....Univ. Kans.
Douglas E. Brown.....Colo. Sch. Mines
Frank L. Brown.....Univ. Tulsa
Harry L. Brown.....Colo. Sch. Mines
George W. Bruce.....Univ. Wichita
Robert Bulla.....Mo. Mines & Met.
John Bychok.....Univ. N. H.
David T. Byrne.....Univ. Pittsburgh
Francis W. Byrne, Jr...Univ. Pittsburgh
John P. Campbell, Jr....La. State Univ.
John D. Carmichael.....Univ. S. Calif.
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Alfred J. Christenson.Mich. Min. & Tech.
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Otis H. Collingwood.....Univ. Wichita
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George P. Conard, 2nd.....MIT
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James A. Crate.....Univ. Pittsburgh
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J. W. Cunningham...Carnegie Inst. Tech.
Robert B. Daniel.....Colo. Sch. Mines
Richard M. Dannenberg, III Univ. Okla.
William J. Davies.....Wash. Univ.
Charles DeAinza.....Univ. S. Calif.
Robert W. Decker.....MIT
Earle V. Dempsey.....Univ. Nev.
Joseph G. Dempsey.....Univ. Tulsa
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Clifford W. Dunham.....Univ. S. Calif.
James P. Dunn.....Univ. Tulsa
Jacob Eichler.....CCNY
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William D. Elliott.....Univ. Tulsa
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Drilling and Sampling Unconsolidated Materials

By LEON W. DUPUY,* Member AIME

Introduction

Many articles have been written describing peculiar and particular types of drilling. Little correlation has been made between the character of ground to be drilled and sampled and the type of drilling most desirable for procuring satisfactory samples. In development work, the engineer and metallurgist often desire the recovery of a sample in as physically natural a condition as possible, particularly when the sample must provide material for process tests as well as chemical and physical analyses. This paper describes the results of experimentation in drilling unconsolidated materials carrying titanium minerals in the Magnet Cove area, Ark. The drilling was most difficult in that the ground varied much in consistency, and it was vitally necessary to recover a physically natural sample. Ordinary churn drilling recovered a sample that could be analyzed chemically, but the sample was not in its natural state. The problem was successfully solved by utilizing and further developing methods used in the oil and clay industries.

In the Magnet Cove area of Hot Spring County, Ark., the titanium minerals include rutile, brookite, anatase, leucoxene, and others. They occur in soil, clays, and altered rocks adjacent to novaculite in contact metamorphic deposits. In preparing titanium minerals for use in the industry, it is necessary to know the physical characteristics of the ore. Also it is believed that the particular physical character of the titanium mineral used is just as important as the chemical character. Brookite and rutile, for example, are the same chemically but differ in crystalline structure. In preparing titanium minerals for market, beneficiation is necessary. For the millman to make a satisfactory laboratory test, the sample he uses must be as nearly of the same physical character as he would have from mine run ore.

In the past at Magnet Cove, churn drilling had been done on the properties, and assays of total titania had been obtained. It was found, however, that the total titania was indicative merely of the presence of titania but did not tell the metallurgist the character of the material or even give him the slightest indication of what he might expect to recover. When the Bureau of Mines entered the field in the winter of 1947 and 1948, it was therefore necessary that a natural sample be recovered.

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LIMITATIONS IN ORDINARY PRACTICE

The churn drilling that had previously been done had shown that the occurrence of titanium-bearing mineral was somewhat widespread. The samples were, however, completely beaten up and in a finely powdered state. The minerals had been slimed, and such ore dressing tests as were made from the churn-drill samples were found to be worthless.

Test pitting and outcrop sampling had provided satisfactory samples of surface ore but did not represent the entire ore body. A quantity of rutile had been produced from the surface residual concentrations in the westerly part of the cove, but production ran into metallurgical trouble as depth was attained. Representative deep samples upon which ore dressing research might depend were needed.

FIG 1—Diamond drill and water pump used at Magnet Cove. Set-up using portable iron pipe tripod.

Diamond Drill Experience and Experimentation

First it was decided that diamond drilling might be the best method of approaching the problem. In the eastern part of the cove the ore near the surface was a residual material, including soil, clay, and quartz boulders containing very jagged crystalline edges. A shot drill was, of course, out of the question because of the washing effect of the drilling water and the fact that the core would therefore be completely ground up. Using a diamond drill with a normal core barrel, it was found that the water washing between the end of the inner tube and the bit completely destroyed the core. It was decided to use the newer type of core barrel with a long inner tube similar to that manufactured by several firms.

DRILL USED

The diamond drill used by the Bureau of Mines at Magnet Cove was a Longyear Junior Strateline equipped with standard tools. Subsequently, a cathead for drive piping was installed on the machine. Fig 1 pictures the equipment utilized.

FIG 2—Diamond drill equipped to use cathead for drive piping.

CASING BIT

At one time during the operation the driller believed that he could attain good core recovery by using a casing bit and just pushing it down through the soil and rotating it a little when he hit a boulder. The hard quartz boulders quickly destroyed the casing bits, and core recovery was nonexistent.

CORE BARREL

The core barrel adopted for the project was the Series M barrel equipped with a long inner tube. Use of the barrels on the unconsolidated ground showed first that the rotation speed and pressure on the bit have a great deal to do with recovery. After much experimentation, it was found that the most generally satisfactory method of drilling in soft ground was to "feel it out" and to use reasonably slow rotation and a minimum volume of water. High rotation speed was not practical, since the quartz boulders lying in the unconsolidated material were rough, jagged, and hard. When a rapidly rotating bit contacted such a rough, hard object, the diamonds were torn out almost immediately. There were instances where the bit was completely ruined in a few revolutions. High speed also requires much more water. High water pressure—that is, using abundant water—washed away the core. Even with the long inner tube the washing of the solutions in the bottom of the hole was too vigorous to permit the slowly advancing bit to capture the soft material before washing it away. In these instances, of course, sludges were saved and comparisons made between the character of the core and the character of the sludge. Holes were started at NX size and reduced to BX when necessary. It is possible that using sizes larger than NX might have resulted in better recovery of core. The high cost of larger barrels, bits, and accessories than NX was the principal reason for starting NX. The losses of material were principally in the loose, unconsolidated soil and clay. A number of holes were drilled following the preferred practice described, but the operation could hardly be called successful. Utilizing the slow rotation and minimum water method, core recovery occasionally amounted to 100 pct but on the whole was little better than 50 or 60 pct most of the time.

USE OF DRIVE PIPE WITH ROTARY CORE DRILLING

A page was borrowed from the book of clay sampling. A cathead was rigged on the side of the drill (Fig 2), and the drive-pipe method of sampling utilized during the penetration of the soft material. The first runs, when no cathead

FIG 3—Bucket drill moving onto new set-up.

was available, were made by taking the wire line off the hoist drum and replacing it with a manila rope. Drive piping was then done, using the hoist drum as a cathead. The drive pipe was run until it was well-seated in a hard boulder before changing to rotary diamond drilling. The cutting shoe of the drive pipe made a seat in the boulder or rock from which the diamond drill could take off without running on any jagged edges. BX casing was used for the drive pipe. The shoe was the same size as the BX casing, so that when a boulder or hard rock was encountered and the drive pipe pulled, the rock could then be drilled with a standard NX bit. The speed of drilling was increased materially, and it was also possible to use heavier pressure when desired. As soon as the hard rock was passed, the drive pipe was put back in the hole, and the hole was sunk drive-pipe fashion down to the next hard stratum or boulder, then diamond-cored through the boulder, and so on, to the end of the hole. With the adaptation of the combination drive pipe and rotary method, it has usually been possible to recover 100 pct of the core in natural and true form and to disregard sludges. When diamond drilling, sludges were still saved in the settling tubs as a matter of insurance in case something went wrong and until after the sample was inspected. If the core sample was satisfactory, the sludge was thrown away. In some instances, portions of the core have been lost by washing when small, soft clay deposits exist inside the harder boulders or between layers of harder rock. Usually, however, the driller was able to make a fair job of core recovery. The one difficulty with the method is that the average diamond driller dislikes drive piping very much and will use every excuse conceivable to avoid it, for it is hard work. With the right kind of a man on the rig, one who can be persuaded that core recovery is what is desired, core recovery will be procured.

Using the combination drive pipe and diamond drill, a driller and helper are required. A sampler can take care of two rigs, so that labor requirements per rig are 2½ man-shifts. Using the drill crew as samplers reduces footage 20 to 30 pct. The rig averages about 13 ft per shift, including moves and drilling holes 170 ft deep. Runs are limited to 3 ft, except in consolidated material.

FIG 4—Typical buckets. *Top* Door-type bucket. *Bottom* Sawtooth bucket.

Before use of the drive pipe with runs limited to 2-ft lengths, the diamond drill averaged 7 ft per shift.

While experiments with a diamond drill were being conducted, a second method of coring, that of utilizing a Baker cable-tool core barrel with a bucket drill and a churn drill, was successfully developed.

Bucket-drill Experience and Experiments Adapting the Baker Core Tool

THE BUCKET DRILL

The bucket drill has been described in several Bureau of Mines publications.[1,2,3] Former Bureau projects, for example, at Coso Hot Springs[1] utilized a bucket drill with a simple rotation utilizing ring gear, cross head, and Kelly bar. The rig used at Magnet Cove was a variation of that earlier machine. It includes not only the features of the original bucket drill with the ring-gear drive but also had an auxiliary churn-drill device that could be utilized to break boulders and do some churn drilling. The rig was mounted on a four-wheel-drive truck and was quite mobile (Fig 3). Fig 4 shows some of the tools utilized in sinking the holes.

USE OF TOOL

The equipment gets its name (bucket drill) from the bucket-type appearance of the main tools, such as the trap-door-bottom bucket shown in Fig 4 *top*. The buckets may be of any diameter desired. In this particular instance the diameter was 20 in. The trap-door bottom acts as a sort of auger bit which peels the clay and small boulders out of the hole up into the bucket. Usually, about 12 in. is cut on each trip of the tools into the hole. Another useful tool was the sawtooth bucket, Fig 4 *bottom*. The sawtooth bucket acts somewhat as a crosscut saw. It cuts a solid core through reasonably consolidated material, that is, material that ordinarily is considered soft or material that might be mined with a power shovel, perhaps without blasting, but yet is not too hard. There have been times when real hard rock, such as flint, has been cut with sawtooth buckets though cutting very hard material is not economical.

FIG 5—Swinging the mother hubbard bit.

[1] References are at the end of the paper.

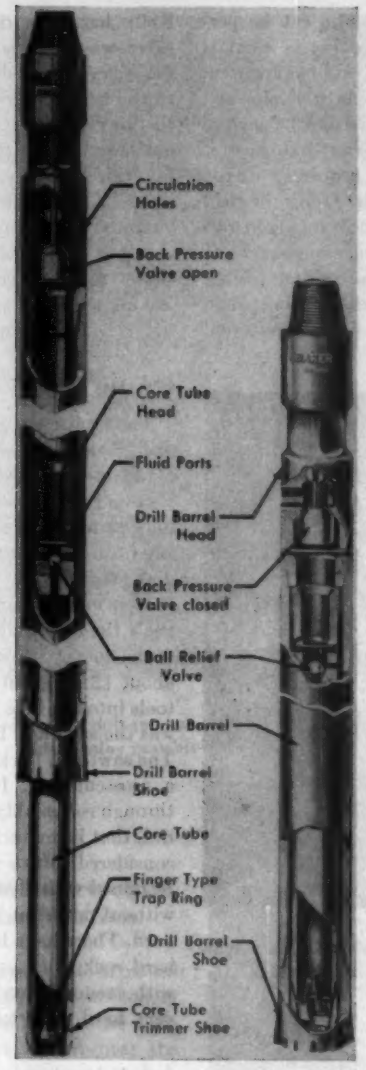

FIG 6—Baker cable tool core barrel.

The sawtooth bucket is probably used more than any other on bucket-drilling jobs because it is simpler to manipulate and will handle boulders much better than the trap-door bucket. In some instances, if water is in the hole, the trap-door bucket is equipped with flaps of flexible material on the inside, so that the pressure of the water as the bucket is pulled out of the hole inside the bucket will shut the flaps and make it possible to withdraw a bucketful of mud. Otherwise, the mud will run out the bottom of the bucket. A number of other tools are also used, but the two mentioned are perhaps the most common buckets. A rock bucket used by a California firm consists of heavy straight steel teeth somewhat like shovel teeth inserted on the side of the bucket with the flat edge parallel to the circumference and the long part of the tooth flush with the outside of the bucket. It has been quite successful in drilling through cobblestones and cemented material in foundation work.

The greatest bugaboos in bucket drilling are handling or passing through the occasional large, hard boulders. In the Magnet Cove work a "mother hubbard bit," shown in Fig 5, was acquired from the oil fields and adapted to the bucket rig. The mother hubbard bit in this instance weighed about 1400 lb, and the bit face was dressed to 20 in. It was utilized with the churn-drill mechanism with which the rig was equipped. The heavy bit was a little hard to hold with the comparatively small brake drums on the bucket drill but was very effective in shattering such large boulders or hard ribs as were found. The unsatisfactory thing about the use of a mother hubbard bit was that it was getting back to churn drilling, and the physical character of the sample was being changed, which was a feature not wanted.

BAKER CABLE-TOOL CORE BARREL

The Baker cable-tool core barrel, details of which are shown in Fig 6 and 7, is a tool that has been used in the oil fields of Pennsylvania and other parts of the country,[4,5] and sometimes is called a wire-line core barrel, although the latter name is used for other designs of core barrels also. In ordinary mine-sampling work the Baker tool is relatively unknown. The tool was tried when it was found that it was necessary to use a mother hubbard bit in the bucket-drill holes too frequently.

The core barrel (Fig 6) consists of two main parts—an outer drilling barrel and an inner core-retaining tube, or inner barrel. The inner tube does not move upward at any time after the coring is begun. It rests on the bottom of the hole until the tool is pulled out of the hole. An outer drilling barrel slides up and down on the inner tube and cuts away the formation around it by churn-drill action, permitting the inner tube to drop. As shown in Fig 6, the top of the inner tube is flared a little, permitting the bottom of the drill-barrel head to tap it should it hang up a little in sliding down over the core. Thus, in effect, the inner tube is a drive pipe.

An important feature of the inner tube is the ball-check valve, or a relief valve, that permits any water trapped in the core tube or inner barrel to escape as the tube fills with core. The ball valve also prevents any fluid under heavy pressure from above from acting upon the core.

The parts that make up the assembly are illustrated and labeled in Fig 6 and 7. The drill-barrel shoe is made with a clearance in the cutting edge which allows the barrel to drop freely in the hole. The cutting teeth of the drill shoe are staggered to prevent key seating and are faced with hard metal.

The drill shoe or bit is connected to the lower end of the drill barrel with a special tool joint thread. Since the inside diameter of the shoe is smaller than the inside diameter of the drill barrel, the shoulder thus formed prevents un-

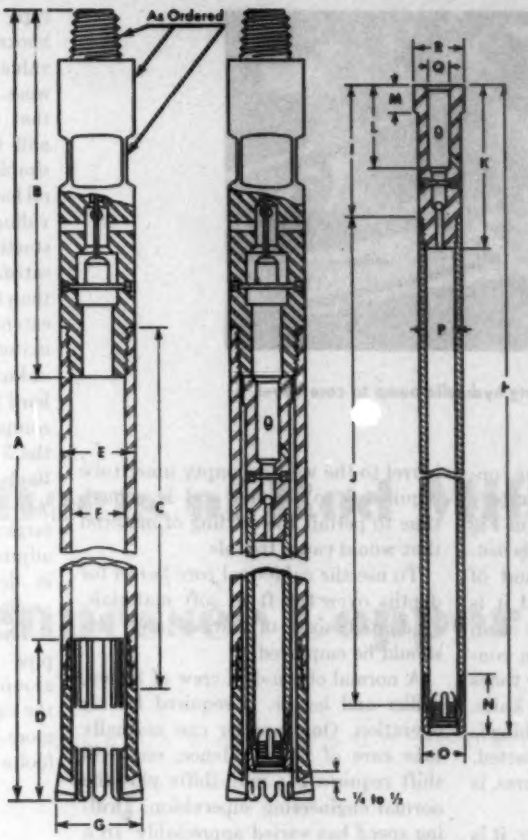

FIG 7—Baker cable tool core barrel.

Dimensional Data for Baker Cable Tool Core Barrel.

Size of Barrel	A	B	C	D	E	F	G	H	I
5	11 ft. 8 in.	32	8 ft. 6 in.	12	4⅜	3¼	Gauge	8 ft. 10½ in.	13½
6	11 ft. 8 in.	32	8 ft. 6 in.	12	5¼	4	Ordered	8 ft. 10½ in.	13⅝

Size of Barrel	J	K	L	M	N	O	P	Q	R
5	7 ft. 7 in.	15	8	2½	3½	2¾	2¼	2	3⅛
6	7 ft. 7 in.	15	8	2½	3½	3 7/16	2 13/16	2	3⅜

intentional removal of the core-retaining tube (inner barrel) which is provided with a shoulder at its upper end. The inner surface of the drilling shoe has watercourse grooves to allow free passage of fluid from within the drill barrel to the cutting edge of the drill shoe. The core retaining spring, or ring, fits inside the inner tube and prevents the dropping of core.

The opening of the valve in the drilling barrel (outer barrel) at the upstroke permits fluid to enter the barrel, and the closing of the valve in the core retaining tube on the downstroke prevents the fluid from entering the core retaining tube. This action on the downstroke which closes both valves produces a hydraulic effect which directs the fluid between the inner barrel and the outer barrel with such force that it keeps the teeth of the drill shoe free from cuttings, and often makes it possible, particularly when a new drill barrel shoe is used, to drill certain formations as fast or faster than with a standard churn-drill bit. It will be noticed in the sketches that ports in the barrel permit the free entrance of the drilling solutions or muds when the outer barrel valve is open.

The best results were obtained by using an intermediate churn-drill stroke (3 to 4 ft) rather than a long or a short stroke, and a drilling speed of 32 to 35 strokes per minute. Although the manufacturer recommends using a stiff rope socket, the best results were obtained with a swivel socket, unblocked, permitting the outer barrel to rotate.

In actual practice a few coarse cuttings usually settle on top of the solid core within the core barrel. These coarse cuttings are useful for panning in the field to determine if the material being cut carries mineralization. In going through clays and sticky material, the core often wedges tight within the barrel, and a hydraulic hand pump is used to extract the core in the barrel.

FIG 8—Attaching hydraulic pump to core barrel.

A picture of the hand pump being connected to the core barrel preparatory to extracting the core is shown in Fig 8. When the core is extracted, it is usually found that a certain amount of sludge adheres to the core, and it is often necessary to scrub the core clean with a wire brush to keep from contaminating the sample. At other times the material is scraped off with a knife. With hard-rock cores simple washing is sufficient. After the core is extracted, the procedure of handling, of course, is familiar to all.

When drilling through soft clay, it is often found that the true drive-pipe action has taken place and that the core has somewhat elongated in the barrel. It is easy enough to compensate for that elongation by calculation should it become necessary to divide the core at any particular interval.

At the Magnet Cove project wear and tear on the core barrel have been comparatively light, although the spare parts are always carried in stock as a guarantee against shut-downs. The cost of operations utilizing the core barrel depends largely upon the efficiency of the drill crew, the character of the rig, the weight of tools, the depth of hole, and the character of the ground. The use of the hydraulic hand pump for removing core is a little tedious and time-consuming. Much time is saved if a second inner tube is ready and assembled so that the driller can proceed with the next core run while the sampler and drill helper remove the core from the last run. The hole is always bailed as soon as the run is finished to keep heavy particles from settling out and interfering with the next run. Changing the bit and outer barrel to the waiting empty inner tube requires 5 to 10 min and is enough time to permit the settling of material that would cause trouble.

To use the cable-tool core barrel for depths over 100 ft in soft materials, graduated sizes of barrels and bits should be employed.

A normal churn-drill crew of 2 men, driller and helper, is required for rig operation. One sampler can normally take care of 2 rigs. Hence, one drill shift requires 2½ man-shifts plus the normal engineering supervision. Drilling speed has varied appreciably. In a shallow hole (under 50 ft) the driller often makes 20 to 25 ft per 8-hr shift. In deeper work 10 to 15 ft of drilling in a shift is more common. For October, with 44 drill shifts, a standard-type churn-drill rig, using a core barrel, drilled 517 ft in 5 holes, including moving time. As experience is obtained, performance is becoming better.

USE OF STANDARD TYPE CHURN DRILL

Since the bucket drill's churn-drill mechanism proved the value of the cable-tool core barrel but was not designed for continuous churn drilling, a regular standard churn drill was moved in. Operations with a standard churn-drill rig have been found to be far more satisfactory than with the bucket-drill rig. The speed of drilling was almost doubled.

Conclusions

The bucket drill, when doing the work for which it was designed, recovers a large sample with its auger-type bucket and with the sawtooth bucket. That sample, of course, is very valuable, particularly for metallurgical work. To have a large sample and one that will supply ample bulk for the mill testing laboratory is a very desirable result. The cable-tool core barrel has proved quite satisfactory in providing core in unconsolidated material starting from the surface. It is more satisfactory for development purposes than the bucket drill in ascertaining the extent of an ore body of unconsolidated material where conditions are relatively unknown and where transition from hard to soft material is rapid. Where a comparatively large sample is desired, the 3 in. diam sample provides a relatively large core which can be properly split and provide a satisfactory metallurgical sample. The tool is a valuable adjunct of the standard churn drill and in development work could well be profitably utilized more frequently.

The diamond drill, with its drive-pipe combination in unconsolidated ground, gave equally as good results as the cable-tool core barrel but required more physical exertion and was less foolproof.

Acknowledgments

Grateful acknowledgment is given to A. B. Needham, Donald F. Reed, S. P. Holt, and George W. Lester, mining engineers of the Bureau of Mines, for active assistance and participation on the project; to J. R. Thoenen, chief of the Tuscaloosa Branch, for his assistance and consultation; and to Lowell B. Moon, chief of the Mining Division of the Bureau of Mines, for his aid and counsel in the prosecution of the projects.

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Effects of Rod Mill Speed at Tennessee Copper Company

By J. F. MYERS* and F. M. LEWIS,* Members AIME

The purpose of the mill tests reported herein, was to determine the relative power efficiency of fast and slow rod mill speeds on the ores of the Tennessee Copper Co.

The tests were carried out at the Isabella Mill of the Tennessee Copper Co. under normal operating conditions. Every effort was made to keep the ore supply and other conditions constant, but it will be noted that some slight variation did occur.

The open circuit 6 by 9 rod mill, and ore, used in these tests have been previously described.[1] Four motor drive pinions were available and the tests were performed in the following manner: each pinion was used to drive the mill for a period of one week. Constant sampling prevailed during the test run, and a composite sample for each speed test was made. Realizing that some slight liner wear took place during the four-week test-run, and that some slight variation of the ore may have taken place, a second and then a third series of four-week test-runs were made with the four different pinions.

The screen analysis of each of the three-week run samples at the various speeds were composited and the results are shown in Table 1.

The authors feel that the 12 weeks of operation consumed during these test-runs would represent fairly the effect of each mill speed. The data of line 37 show that within the error of sampling and plant operation, the tons of minus 65-mesh material generated per horsepower hour was the same at all four speeds.

Obviously, rod and liner consumption could not be determined for each mill speed in so short a time. The rod load was maintained at a uniform level throughout the series of tests.

The authors have operated rod mills at various speeds over the past several years, and it is their observation that rod consumption is directly proportional to the mill speed. Likewise, that the rod consumption per unit of work performed is a constant, providing that all other operating factors remain the same.

It is a well known fact that the efficiency increases in a ball mill as the speed decreases. This is due to lateral segregation of the large and

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[1] References are at the end of the paper.

Table 1 . . . Data on Various Rod Mill Speeds Isabella 6 by 9 Rod Mill— 2½ In. Rods

Line Number		A	B	C	D
1	Tons per day	1,100	1,100	1,100	1,100
2	RPM	26.5	24.0	22.7	21.4
3	Discharge opening, in.	24	24	24	24
4	Horsepower input	194	181	175	170
5	Mill dilution	78.9	79.0	78.8	78.6
6	Critical speed, pct	82.4	74.6	70.5	66.5
	Mill Feed: Mesh	**Weight, Pct**	**Weight, Pct**	**Weight, Pct**	**Weight, Pct**
7	0.742	3.3	5.7	2.9	3.1
8	0.525	21.2	15.6	13.5	10.4
9	0.371	18.3	16.1	16.9	16.4
10	3	13.5	12.1	13.6	13.0
11	4	8.7	7.9	8.5	9.1
12	6	6.0	6.0	5.8	6.7
13	8	3.7	4.2	4.7	5.1
14	10	3.0	3.7	3.7	4.1
15	14	2.2	2.9	2.8	3.2
16	20	2.0	2.8	3.0	3.1
17	28	2.0	2.9	2.8	3.1
18	35	1.9	2.9	2.6	2.9
19	48	1.9	2.9	2.5	2.8
20	65	2.0	2.7	2.6	2.9
21	100	1.8	2.1	2.2	2.4
22	200	2.4	3.0	3.3	3.4
23	−200	6.1	6.5	6.6	6.3
	Mill Discharge: Mesh				
24	14	1.8	1.6	1.4	1.8
25	20	4.0	3.2	3.7	4.4
26	28	7.5	6.6	7.0	7.7
27	35	10.6	11.1	10.7	11.0
28	48	11.2	12.2	11.9	11.5
29	65	11.0	12.5	13.2	12.9
30	100	11.3	10.9	10.5	10.1
31	200	13.6	14.2	15.0	14.2
32	−200	29.0	27.7	26.6	26.4
	Tons, 65 Mesh Material				
33	In feed	113.3	127.6	133.1	133.1
34	In product	592.9	580.8	573.1	557.7
35	Generated	479.6	453.2	440.0	424.6
36	Generator per hour	19.98	18.88	18.33	17.69
37	Per hp-hr	0.1030	0.1043	0.1047	0.1041

small balls.[2] Balls respond individually to mill speeds and other factors. Rods, being rigid from end to end, show no tendency to segregate according to size, and hence, respond directly to speed and/or increased contact with each other and the mill shell.[1]

Conclusions

The conclusion reached (see line 37 of Table 1) is that with all other factors the same, the work accomplished in a fine crushing rod mill is directly proportional to the rotating speed.

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Temperature Compensation of Old Type Askania Magnetometers

By T. KOULOMZINE,* Member AIME

Introduction

The theory of the Askania magnetometer, as well as a complete discussion of all factors influencing magnetometer readings, is very ably described by J. Wallace Joyce.[1] We will assume that the reader is thoroughly familiar with this theory and we will use whenever possible the same notations for the physical values involved in the theory. On the other hand, we believe that the principal formulas of the magnetometer can be deduced much more easily by the use of differential calculus than by the methods employed by Joyce. Consequently, we are presenting herewith a resumé of the theory of the vertical magnetometer in order to determine the correct formula of the temperature coefficient which we propose to compensate.

Short Theory of the Vertical Magnetometers

We shall accept the following notations:

m = total mass of the magnet system, in grams.

g = acceleration of gravity, in dynes.

a = projection on the axis of the magnet system of the distance between the axis of support and the center of gravity of the magnet system, in centimeters.

h = projection on the perpendicular to the axis of the magnet system of the distance between the axis of support and the center of gravity of the magnet system, in centimeters.

$M = 2pL = M_e$ magnetic moment of the magnet system.

Z = vertical component of the earth's magnetic field.

θ = deflection angle of the magnet system.

= focal length of objective lens in the optical system

S = scale reading.

In a vertical magnetometer the axis of the magnet system is kept horizontal within 2°. Therefore, referring to Fig 1, we see that the magnetic torque of the magnet system influenced by Z must be counterbalanced by the gravity torque.

$$MZ \cos \theta = mga \cos \theta + mgh \sin \theta \quad [1]$$

or dividing by $\cos \theta$

$$MZ = mga + mgh \tan \theta \quad [2]$$

If we now move to another magnetic station and the temperature conditions change, the values of all the variables will change also:

M, a, and h under the influence of temperature.

Z, both with time and space.

θ and S, as a result of all the above changes.

Taking increments in Eq 2 we obtain:

$$(M_e + \Delta M)(Z + \Delta Z) = mga, + mg\Delta a + mg(h + \Delta h) \tan (\theta + \Delta\theta) \quad [3]$$

but $\tan (\theta + \Delta\theta)$, because θ is small, can be replaced by $\tan \theta + \tan \Delta\theta$; in fact

$$\tan (\theta + \Delta\theta) = \frac{\sin \theta \cdot \cos \Delta\theta + \cos \theta \cdot \sin \Delta\theta}{\cos \theta \cdot \cos \Delta\theta - \sin \theta \cdot \sin \Delta\theta}$$

but $\sin \theta \sin \Delta\theta \to 0$

$\tan (\theta + \Delta\theta) \to \tan \theta + \tan \Delta\theta$. Furthermore, neglecting all terms of the equation containing two differentials or a differential and a $\tan \Delta\theta$, Eq 3 becomes:

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[1] References are at the end of the paper.

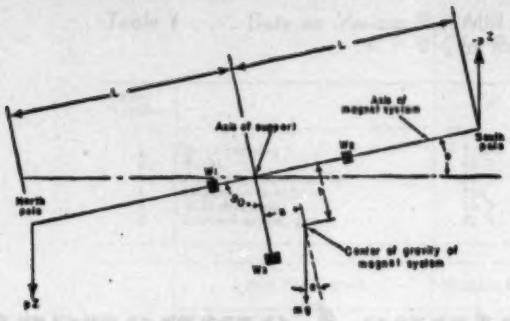

FIG 1—A vertical magnetometer. In this drawing distances a and h are very much exaggerated. In a real magnetometer they are of the order of 0.01 cm.

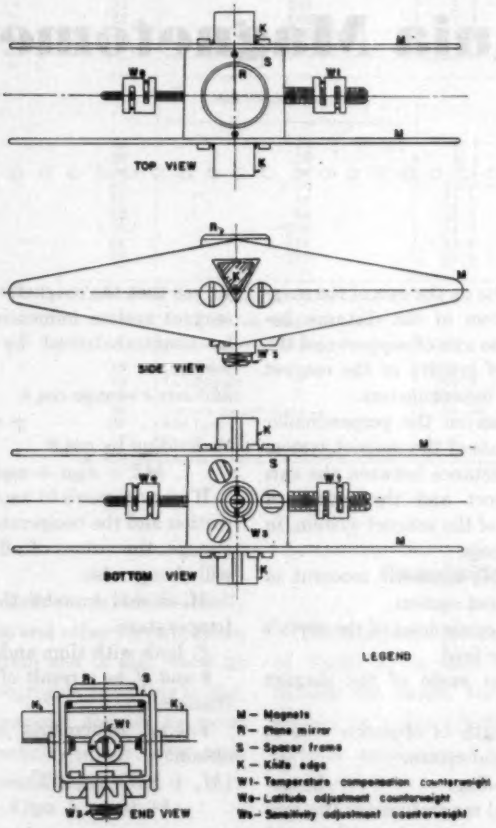

FIG 2—Diagram of modern temperature-compensated magnetic system.

$$M_o Z + Z\Delta M + M_o \Delta Z = mga_o + mg\Delta a + mgh \tan\theta + mgh \tan\Delta\theta \quad [4]$$

subtracting Eq 2 from Eq 4 we obtain:

$$Z\Delta M + M_o \Delta Z = mg\Delta a + mgh \tan\Delta\theta \quad [5]$$

or

$$\Delta Z = \frac{mgh}{M_o} \tan\Delta\theta + mg\,\frac{\Delta a}{M_o} - Z\,\frac{\Delta M}{M_o} \quad [6]$$

This is the basic equation of the magnetometer.

It can be shown easily from the study of the optical system that $\tan\Delta\theta = \frac{S - S_o}{2f}$, while Δa and ΔM vary only with temperature changes; therefore

$$\Delta Z = \epsilon_o (S - S_o) + T_o (t - t_o) \quad [7]$$

where

$$\epsilon_o = \frac{mgh}{2fM_o} \quad [8]$$

is the scale coefficient of the magnetometer

and

$$T_o = -Zu + \frac{mga_o}{M_o} p \quad [9]$$

is the temperature coefficient of the instrument

$u = \frac{\Delta M}{M_o}\frac{1}{t - t_o}$ being the temperature coefficient of the magnetic moment

and

$p = \frac{\Delta a}{a_o}\frac{1}{t - t_o}$ The temperature coefficient of the distance between the center of rotation and the projection of the position of the center of gravity on the axis of the magnet system.

Furthermore from Eq 2 we find that when θ is small or zero,

$$a_o = \frac{M_o Z}{mg} \quad [10]$$

Therefore Eq 9 becomes:

$$T_o = -Z\,u + Z\,p = Z\,(p - u) \quad [11]$$

where u is always negative. This means that M decreases with any increase of temperature. On the other hand, p is naturally positive, the distance between the center of gravity and the point of support of the magnet system increasing with rising temperature. Thus, unless compensation is provided for, a symetrically built magnet system will have a positive temperature coefficient.

Temperature Compensation of the New Magnetometers

The modern temperature-compensated magnet system contains two counterweights along the axis of the system (Fig 2). The counterweight near the south pole of the system is on an invar spindle while the one to the north is on an aluminum spindle. In order to keep the system in a horizontal position, the center of gravity of the entire system has to counterbalance the magnetic torque and therefore (in the northern hemisphere) is to the south of the knife edge. With increasing temperature all parts of the system expand symmetrically, with the exception of the two spindles which shift the center of gravity to the north and thus produce a contraction of the value of a and

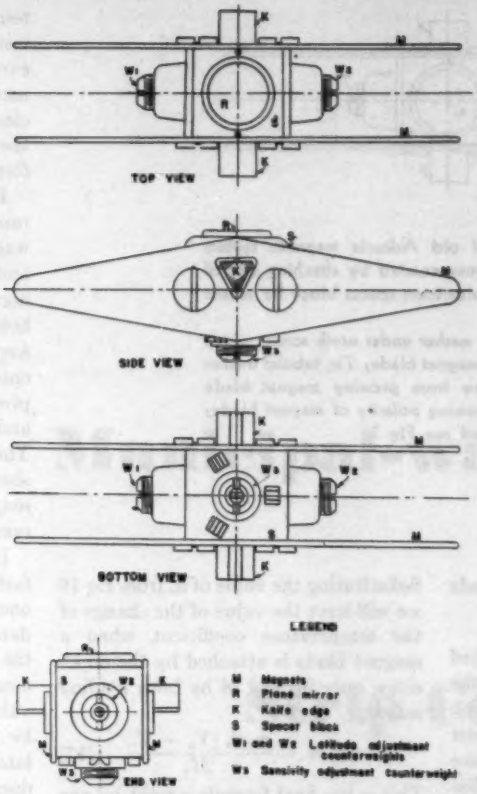

FIG 3—Diagram of old type Askania magnet system which is not temperature compensated.

a negative coefficient p. With appropriate values of the weights *We* and *Wt* and a proper location of *Wt* along the aluminum spindle, a complete temperature compensation can be obtained, the value of p being made negative and equal to the negative value of u:

$$p = u \qquad [12]$$

Temperature Compensation of the Old Magnet System

The theory of this compensation was developed by the author in the spring of 1933, while he was engaged in repairing a magnetometer belonging to the Mines Domaniales de Potasse d'Alsace, in France. It is based on the fact that in the old system the spacer block is made of aluminum which has a coefficient of expansion different from that of the cobalt steel out of which are made the two magnet-blades (see Fig 3).

If an old magnet system is put together with perfect symmetry, it would have in the Ontario-Quebec mining districts of Northern Canada a temperature coefficient of:

$$T_c = Z\,(p - u)$$

where Z would be of 0.58 gauss, p the coefficient of expansion of aluminum 2.4×10^{-5}, u the temperature coefficient of the magnetic moment 14.10^{-5}. Thus, using gammas (1 gamma = 1/100,000 gauss)

$$T_c = 58{,}000\,[2.4 - (-14)]\,10^{-5}$$
$$= 0.58 \times 16.4 = +9.5 \text{ gammas}$$

Let us consider now the effect of a nonsymmetrical attachment of a magnet blade to the aluminum spacer block.

The position of the common center of gravity of the whole system depends on the position of each of the centers of gravity of the two blades and the three counterweights. When expansion occurs the relationship may be expressed by the formula:

$$ma_c p = m_1 l_1 v_1 + m_2 l_2 v_2 + m_3 l_3 v_3 + m_4 l_4 v_4 + m_5 l_5 v_5 \qquad [13]$$

where m_1, m_2 . . . m_5 are the respective masses of the various parts of the system, l_1, l_2 . . . l_5 the distances to the centers of gravity or to the points of attachment and v_1 . . . v_5 the coefficients of expansion of the different materials involved. Correspondingly, p will be expressed by a polynomial:

$$p = \frac{m_1 l_1 v_1}{ma_c} + \frac{m_2 l_2 v_2}{ma_c} + \ldots + \frac{m_5 l_5 v_5}{ma_c} \qquad [14]$$

If any term of this polynomial becomes sufficiently large and negative so as to match the value of the negative u, the temperature coefficient of the magnetometer will be considerably reduced if not actually annulled.

Let the distance between the axis of the knife edge and the screws holding the magnet blades be $l_4 = 0.9$ cm; the coefficient of expansion of aluminum forming the block is:

$$V_a = 2.4 \times 10^{-5}$$

while the coefficient of expansion of the cobalt steel is:

$$V_c = 1.27 \times 10^{-5}$$

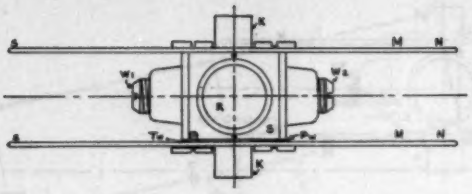

FIG 4—Diagram of old Askania magnetic system partially temperature compensated by attaching one of the magnet blades to aluminum spacer block by means of north screw only.

Legend: *Pw*, paper washer under north screw, which is tightened and holds magnet blade; *Tw*, tubular washer that keeps south screw from pressing magnet blade against block; N-S, showing polarity of magnet blade; for remainder of legend see Fig 3.

finally the mass of each magnet blade is:

$$m_b = 10.8 \text{ g}$$

If one of the blades is to be attached to the aluminum spacer block by the north screw only instead of by both screws which normally press it against the block, any increase of temperature will result in the elongation of the distance between the axis of rotation and the point of attachment, that is, the screw, this according to the coefficient of expansion of aluminum, while the distance between the center of gravity of the blade and the same point of attachment will vary according to the coefficient of expansion of steel.

Thus, an increase of 1°C will shift the center of gravity of the blade towards the north pole of the magnet system for a distance of:

$$(V_a - V_s)\, l_b$$

and the polynomial giving the value of p (Eq 14) will be changed by a term:

$$p' = -\frac{m_1 l_b (V_a - V_s)}{m a_o} \qquad [15]$$

The corresponding effect on the value of the temperature coefficient of the magnetometer will be:

$$T_c' = -\frac{Z m_1 l_b (V_a - V_s)}{m a_o} \qquad [16]$$

Substituting the value of a_o from Eq 10 we will have the value of the change of the temperature coefficient when a magnet blade is attached by the north screw only instead of by both holding screws:

$$T_c' = -\frac{m_1 g l_b (V_a - V_s)}{M_o} \qquad [17]$$

This is the final formula sought by our theory.

It is interesting to note that although the temperature coefficient T_c is function only of Z, u, and p, T_c' is independent of Z but depends on the mass m_1 of the blade and on the magnetic moment M_o of the entire system.

Substituting numerical values of $m_1 = 10.8$ g; $l_b = 0.9$ cm; $V_a - V_s = 1.13 \times 10^{-6}$ we obtain:

for

$M_o = 1500\ \Gamma\ \text{cm}^3$	$T_c' = -\ 7.18\Gamma$
$M_o = 1000\ \Gamma\ \text{cm}^3$	$T_c' = -10.77\Gamma$
$M_o = 700\ \Gamma\ \text{cm}^3$	$T_c' = -15.18\Gamma$

In areas of a high value of Z where T_c is usually around +9.5 gammas it is evident that the loosening of the south screw of one of the blades of the magnet system brings the total value of the temperature coefficient of an old-type magnetometer very close to zero.

Our organization has reduced the temperature coefficients of all its old instruments by this method and, in every case, the experimental measurements of the new temperature coefficient were found to check closely with the predicted values calculated by the formula, Eq 17.

In practice it was found that the best results were obtained if a small paper washer was placed between the blade and the aluminum block under the north screw which was kept tight to hold the magnet blade. The loosened south screw is kept in place and tightened against a small tubular washer pressing against the aluminum block and inserted into the hole of the blade. The tubular washer must be just a shade longer than the thickness of the magnet blade, in order that the blade remain free of the screw (Fig 4).

It is interesting to point out that the fact of leaving only one screw to hold one of the magnet blades decreases the danger of slipping of the blade along the aluminum block which often creates considerable changes of zero point values in old magnetometers. It may be noted that the writer has calculated[4] that temperature changes produced differential stresses between the aluminum block and the magnet blade which were of nearly one kilogram for each degree centigrade.

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Municipal-water Needs vs. Strip Coal Mining

BY GREGORY M. DEXTER

Summary

Recent litigation in Pennsylvania between three coal-mining companies and a private water company resulted in the payment by the coal companies of the equivalent of about $500,000 to buy a new water supply to replace that which had been damaged by acid drainage from strip mining. An investigation of the relevant facts indicates that the water could have been treated by spending about $40,000 on equipment and $15,000 yearly for chemicals, labor, and power until the contamination could be reduced about 80 pct. The water company's supply, furthermore, had deteriorated largely by reason of dry weather before stripping was begun by the coal companies. Payment to the water company should not have exceeded $300,000 and could have been as low as $100,000.

Strip mining of coal is common in Pennsylvania. The most important objection to it in Pennsylvania is generally acid pollution of runoff water. An outline of the methods, therefore, that could be used to reduce such pollution, to compare acid-contaminated waters, and to treat such waters to make them satisfactory for public and industrial use is worth-while.

The watershed of the West Penn Water Co. covers about 4.5 square miles, 20 miles west of Pittsburgh, and has two 90,000,000 gal reservoirs supplying about 1,300,000 gal daily for public and industrial use of which 450,000 gal daily are for two railroads.

The pollution arises from weathered derivatives of typical "Coal Measures" rocks, the principal source being pyrite (and marcasite) in Pittsburgh and Rooster coals.

Springs and seeps on hillsides issue from sandstone and limestone formations intersecting shale or clay land surfaces, or from perched water tables. The two reservoirs create an artificial permanent water table. Soap-hardness tests on three seepage samples taken in a dry summer ranged from 150 to 500 ppm. Water sampled came from aquifers above Pittsburgh and Rooster coals, obviating the possibility of contact with pyrite-containing coal.

Since acid contamination of mine waters is the result of chemical reactions of oxygen and water with pyrite, it will be reduced by the exclusion of either air or water.

The Sunnyhill Coal Co. has applied this principle in its "contouring" method of strip mining by burying contaminated coal-waste material under a compact, smoothed-up surface of topsoil, gravel, clay, and sand at a cost

TP 2570 F. Discussion of this paper (2 copies) may be sent to *Transactions*, AIME before July 15, 1949. Manuscript received March 3, 1947; revision received Sept. 28, 1948.

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of about $250 per acre.

Supplementary methods for controlling localized flow of water include the use of cement grouting, sheet piling, chemical impregnation, tar blankets, and bentonite.

Average rainfall on West Penn watershed is probably 40 in. annually of which about 45 pct is surface and ground runoff. Ground runoff is probably about 25 pct. Surface runoff is increased by "contouring."

Infiltration of rainfall ranging from 0.3 to 2.4 in. per hour depends on porosity and moisture content of the ground. Although oxygen dissolved in the infiltrated water, surface evaporation, diffusion, temperature, wind, and barometric effects are slight in the oxidation of sulphur-bearing material, "contouring" by compaction and increased growth of vegetation is a definite help in its retardation.

Soap hardness of contaminated water is affected by weathering of exposed material, resulting first in increased alumina. Increases of hardness in dry weather (amount is reduced by a swamp on a stream) and decreases with rainfall have been shown repeatedly. No increase in hardness of water in dry weather is an indication of the beneficial effect of "contouring."

Soap-hardness tests on water from the lower reservoir of the West Penn Water Co. showed values as high as 200 ppm in a wet year prior to the beginning of new stripping operations in 1941. In the dry year of 1945, they went as high as 500 ppm, thus showing a deterioration prior to 1941. An approximate relationship of acres stripped to average soap hardness shows that, even if 1½ square miles were stripped on a 4½ square-mile watershed, soap hardness should not exceed 700 ppm.

Neutralization of acids is necessary to eliminate errors in soap-hardness values. Comparison of hardness of various waters is significant only when based on calculation as $CaCO_3$.

Comparisons of contaminated waters using a neutral point of 7.0 are misleading. Electrometric methods should be used to determine pH values. Free acids and mineral acids plus sulphates by "standard methods" are misleading. Total sulphates and total solids may be determined by usual methods. Contamination by sulphates in percentage of total salinity often shows worse conditions in alkaline than in acid waters. Recording gauges on streams and adequate sampling are needed to determine pounds of acid sulphates per day. Coal companies can control contamination by chemical treatment of surface water until "contouring" is completed.

Water softened to 150 ppm with total solids as high as 1000 ppm should be acceptable. Sulphates (SO_4) may be as high as 500 ppm.

Acid-contaminated water can be treated chemically to make it satisfactory for public use by lime and soda-ash softening supplemented by sodium aluminate, sodium silicate, aluminum silicate, and septaphosphate, according to local conditions. Removal of alumina offers no difficulties.

In reservoirs, a variable-level draw-off will reduce contamination.

Treated acid-contaminated water with solids limited to a maximum of 3500 ppm can be used in locomotives if advantage is taken of manual control and continuous blowdown which will range from 10 to 20 pct. Reasonable blowdown values may be had with concentration of solids from 10,000 to 20,000 ppm by using various colloids, organics, and other compounds.

Medical testimony and experience in the West with highly contaminated water have proved that treated water containing 1000 ppm sodium sulphate can be used for drinking.

The conclusion is that "contouring" will reduce acid contamination of water. It permits the economic development of thin beds of coal, where 75 to 95 pct is recovered as compared with 50 to 60 pct in deep coal mining, while protecting water supplies.

Geological data for this paper were furnished by Daniel A. Busch, Geologist, Huntley & Huntley, Pittsburgh, Pa.

Introduction

Strip mining has two principal advantages over underground methods: lower cost and more complete utilization of coal because none need be left for supporting pillars.

Three major objections to it are: (1) the unsightly appearance of the spoil banks, (2) the loss of utility of the land surface, and (3) the acid pollution, in this case of runoff resulting from exposure of coal on the surface. The last objection becomes important where the acid runoff is impounded in a reservoir for use as a water supply.

Attempts have been made to reduce similar pollution of acid mine waters from abandoned mines. Study of a similar attempt applied to strip mining will show that improvement of runoff is also possible.

This paper is an attempt to outline methods that will permit development of some strip mines and yet provide communities involved with acceptable water supplies. Reduction of contamination, errors in determining extent of contamination, and requirements for treatment of contaminated acid raw water for domestic and industrial purposes will be discussed.

The companies involved were the West Penn Water Co., the Sunnyhill Coal Co., and two others.

Location and Drainage of Watershed of the West Penn Water Co.

The watershed of the West Penn Water Co. is an area of approximately 4½ square miles, and is located one mile east of the village of Bavington in Robinson Township, Washington County, Pa. The northeastern portion extends across the county line into Findlay Township, Allegheny County. The region is maturely dissected and has a maximum surface relief of approximately 380 ft.

St. Patrick's Run flows in a southwesterly direction and is the main stream of the area (Fig 1). It has two principal tributaries, both unnamed. One flows parallel to Highway No. 22 and enters St. Patrick's Run, a short distance east of the headwaters of the east branch of the lower of two reservoirs. The second flows south along the west side of the watershed and is impounded where it joins St. Patrick's Run by the lower dam to form the west branch of the V-shaped, lower reservoir. An upper dam also impounds the middle portion of this second stream at a point approximately 2500 ft north of the lower dam.

The West Penn Water Co., therefore, has two reservoirs, each with a capacity of 90,000,000 gal. Acid mine drainage comes mainly from the strip mining of three companies, although some is caused by the abandoned deep mines and old country mines. One of these companies is the Sunnyhill Coal Co. whose operating methods will be discussed. The maximum water consumption is about 1,300,000 gal daily of which about 450,000 gal are used by the locomotives of two railroads. All other water is used principally by the residents of two municipalities.

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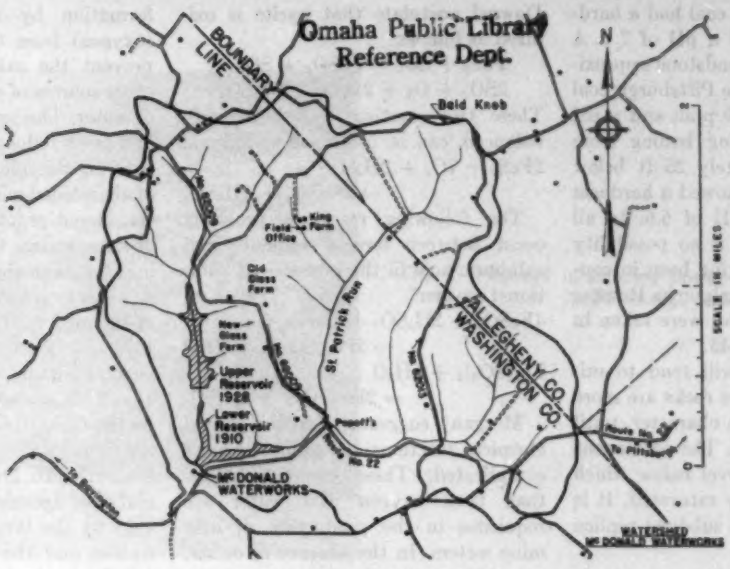

FIG 1—Map of drainage area of McDonald waterworks.

Geology

TYPES OF ROCK RESPONSIBLE FOR INORGANIC POLLUTION OF STREAMS

The rock strata exposed in this watershed include the upper portion of the Conemaugh and the lower portion of the Monongahela series of the Pennsylvanian system. They are strictly, therefore, a "coal measures" section, consisting of alternating beds of shale, sandy shale, sandstone, limestone, coal, and underclay. The Pittsburgh coal and its Rooster coal are both overlain and underlain by all these types of rock.

Inorganic pollution of the streams comes from the weathered derivatives of these strata. The shales, which make up the thickest portion of the exposed strata, are the principal source of aluminum, manganese, and sodium oxides. The sandstones are probably the main source of silicon dioxide, and the limestones, of the calcium and magnesium salts. Limestone, the most soluble of these several rock types, is the main source of temporary hardness in the raw waters. It is also the source of that portion of the permanent hardness due to calcium and magnesium sulphates. Approximately 10 to 12 ft of limestone occur directly beneath the underclay (1 to 2 ft) beneath the Pittsburgh coal. Limestone occurs, in addition, in all the hills where they extend more than 40 ft above the top of the Rooster coal. This limestone is thin-bedded and locally interbedded with limy shale. Nodular limestone is scattered throughout the shale. This limestone interval has a maximum measured thickness of 25 ft where it caps Bald Knob in the northeast corner of the watershed.

The mineral pyrite (and marcasite) is the principal source of pollution in the reservoir waters. It occurs in the Pittsburgh and Rooster coals and their associated shales.

MODES OF OCCURRENCE OF PYRITE IN COAL

Pyrite (FeS_2) may occur in coal as finely disseminated particles, thin discontinuous sheets, balls, lenses, irregular nodules, and as an extremely thin-vein concentration along inclined cleavage partings. Dark shales and clays associated with coal also contain considerable pyrite. These pyritiferous shales and clays may be the roof-slate material or a part of a "bony" section occurring within the coal itself (compare with Thiessen.)[1]

The pyrite-bearing shales and clays are left in and on the spoil-bank material in the stripping of the coal and are exposed in varying degrees to the atmospheric elements. J. W. Paul[1] says, "The amount of sulphur in bituminous coal ranges from 0.5 to 5 per cent, the average being about 1.50 per cent, approximately half of which is organic and the remainder is in pyrite."

WATER TABLES

Two types of water tables are possible, namely, perched and permanent. In an alternating series of rock formations, such as occur in a "coal measures" section, porous and permeable layers are overlain and underlain by impermeable strata such as shale and clay. Sandstone, because of its porosity, serves in the West Penn watershed as a water-bearing formation (aquifer) where it is overlain and underlain by shale. Likewise, the limestone 40 ft above the top of the Rooster coal frequently contains water, because of its solubility in carbonated waters. Springs and seeps are found frequently where the sandstone and limestone formations crop out on the sides of hills. Such springs coming from a perched water table may flow considerable volumes of water during the winter and rainy seasons and dry up in the summer.

The hardness of such waters varies with the amount of flow and the type of rock serving as an aquifer. One drilled well supplying water from the lime-

[1] References are at the end of the paper.

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stone 40 ft above the coal had a hardness of 156 ppm and a pH of 7.1. A spring issuing from sandstone approximately 60 ft below the Pittsburgh coal had a hardness of 280 ppm and a pH of 6.8. Another spring issuing from sandstone approximately 25 ft below the Pittsburgh coal showed a hardness of 500 ppm and a pH of 6.6. In all three instances there is no possibility of the water ever having been in contact with the Pittsburgh or its Rooster coal. The three samples were taken in the late summer of 1945.

Subsurface water will tend to migrate downward where rocks are more or less homogenous in character, until all the pores are filled. The permanent water table is that level below which the rock is completely saturated. It is seldom level, but is a subdued replica of the land surface.

In the absence of a permanent, natural water table, an artificial one has been created by the two reservoirs whose surfaces are at the lowest levels to which the water can flow. Where the permanent table intersects the land surface, seepages occur and there is a flow from the high portions of the water table under the hills into the low areas along the valleys. Since the direction of the flow is never reversed, it is not likely that the permanent water table back under the hills could be contaminated by polluted waters of a reservoir.

Causes of Acid Pollution of Mine Water

Acid contamination varies with numerous factors.[3] Area of coal exhausted is not the sole criterion. Contamination with iron pyrite, for example, may be less at one point than another. Thickness of coal seam, depth of overburden and its character as to permeability, amount of ground water, steepness of surface slopes above the coal seam, dissolved oxygen in water, rate of removal of sulphuric acid and iron sulphate formed, fineness of coal, and exposed surface area of coal and slate with sulphur content are other factors.[4]

The chemical reactions resulting in the pollution of mine runoff waters are complex and only partly understood. The best summary and bibliography is that of Hodge.[4] There are, however, several basic chemical reactions which explain the principal sources of contamination. They involve the oxidation of pyrite (or marcasite). Burke and Downs[5] postulate that pyrite is oxidized as follows:

$$FeS_2 + 3O_2 \rightarrow FeSO_4 + SO_2$$
$$2SO_2 + O_2 + 2H_2O \rightarrow 2H_2SO_4$$

These two reactions, when properly balanced, can be combined as follows:

$$2FeS_2 + 7O_2 + 2H_2O \rightarrow 2FeSO_4 + 2H_2SO_4$$

The following reactions probably occur between ferrous sulphate and sulphuric acid in the presence of additional oxygen[2]

$$4FeSO_4 + 2H_2SO_4 + O_2 \rightarrow 2Fe_2(SO_4)_3 + 2H_2O$$
$$Fe_2(SO_4)_3 + 6H_2O \rightarrow 2Fe(OH)_3 + 3H_2SO_4$$

Morgan[6] suggests that the actual chemical reactions are probably more complicated. These equations show that both oxygen and water are requisites in the production of acid mine waters. In the absence of either, no acid is produced.

Burke and Downs[5] have experimentally demonstrated the extremely slow rate of reaction of the first equation in which pyrite is oxidized to ferrous sulphate and sulphur dioxide. Its rate controls the rate of production of sulphuric acid in mine waters.

Bacteria also may be involved.[6,7,8]

Sayers, Yant, and Leitch[9] show that the passage of moist air over pyrite and marcasite results in a condensate from the moist air which is invariably highly acid. The condensate from moist natural gas which has been in contact with pyrite or marcasite is low in acidity.

Examination of some deep mines that had been sealed showed no sample of water from behind the seals with free sulphuric acid and only one with sulphate of iron in solution.[10] Every sample in open sections of five mines, of long standing, was acid and as a rule highly acid. Three of the mines visited apparently had no acid water either in open or sealed sections. Gas samples from behind seals in those mines generally showed the presence of oxygen to be less than 1 pct.

The practical conclusion, however, is that the exclusion of air or water will reduce acid mine-water pollution.

Reduction of Acid Mine Drainage

BRIEF HISTORY OF MINE-SEALING EFFORTS

The Bureau of Mines, starting in 1925, under the direction of R. D. Leitch, developed the now well-known method of mine sealing. It reduces acid formation by the exclusion of air (oxygen) from the mines in order to prevent the oxidation of pyrite and other sources of sulphur in the presence of water. The sealing of surface cracks and caves reduces the amount of water entering the mines. A complete sealing of abandoned mine entries has not been considered practical, but the draining of mine waters through trapped openings has been shown to be feasible.

A large-scale program of sealing abandoned coal mines was begun in 1933 in West Virginia, Maryland, Ohio, Alabama, Tennessee, and Indiana. This work was carried on jointly by the Ohio River Board of Engineers, the U. S. Public Health Service, several State Health Departments, and Federal relief agencies. It was taken over in 1935 by the Works Progress Administration and the U. S. Public Health Administration and continued for five more years.

A modification of the methods that have been employed in rectifying the pollution of waters draining from deep mines should yield similarly successful results when applied to the waters draining from strip mines. The sealing of coal or shale containing iron sulphide from air (oxygen) will prevent oxidation. Decreasing the amount of water which would normally come into contact with these sources of inorganic pollution should also result in a decrease in the amount of acid formed (Imhoff and Fair,[11] Crichton,[3] LeBosquet and Lyons,[12] Young,[13] Hoak,[14] Meinzer,[15] James,[16] Leitch,[17] Morgan,[6] Babbitt,[18] U. S. Public Health Service,[19,20] and Thiessen[21]).

STRIP-MINING METHODS OF THE SUNNYHILL COAL CO.

The Sunnyhill Coal Co. uses a dragline to remove all the overburden resting on the Rooster coal. The amount removed varies in thickness up to 55 or 60 ft and the width of one cut is approximately 60 ft. The overburden is piled in a long hogback ridge on the downhill side of the cut. The Rooster coal is then loaded out to a depth of about 2½ ft and marketed. The bone and slaty material, which averages 6 ft in thickness and occurs between the bottom of the Rooster coal and the top of the main seam of the Pittsburgh coal, is removed then by a shovel and piled along the base of the spoil bank. The main Pittsburgh vein of coal is then removed and marketed (Fig 2).

The weathered soil, clay, and shale at the top of the undisturbed highwall

FIG 2—Highwall in stripping operations showing Rooster and Pittsburgh coals.

FIG 3—Stripping operation showing spoil material at left and highwall at right.

after the first cut has been completed is bulldozed into the bottom of the first cut in such a manner as to cover completely the loose material from the preceding cut. This blanket of topsoil and clay-shale material is graded with 15 to 16 ton bulldozers, the treads of which work back and forth to build up a compacted cover. This bulldozed fill extends to a foot or so above the top of the Rooster coal in the highwall. The remainder of the overburden removed for the second cut is then piled up as a hogback ridge parallel to the first spoil-bank ridge (Fig 3). The Rooster and Pittsburgh coal seams are removed in the same manner as described for the first cut, and the intervening bone-coal and slaty material is deposited along the base of the second ridge of spoil-bank material (Fig 4).

Successive cuts are made and parallel ridges of spoil-bank material piled up in the manner described until either all the coal of a hill has been removed or the economic limit of overburden is reached. The soil and clay-shale material in the latter case at the top of the highwall are bulldozed into the bottom of the last cut in order to bury the refuse bony coal and slate under a protective blanket of relatively impermeable material. When the last coal of any stripping operation has been removed, bulldozers are used to level off the tops of the spoil banks and fill in undrained valleys and depressions between the ridges (Fig 5). The net result of the bulldozer operation is compacted spoil banks that are contoured for minimum surface exposure and for natural runoff (Fig 6–10). A minimum also of pyrite-bearing coal and shale is on the surface as it has been concentrated in the bottom portions of the spoil banks.

SUPPLEMENTARY PORE-SEALING METHODS

Occasionally stored up water from abandoned mines or springs is released during strip mining. Several methods are available to reduce the amount of such water:

Cement Grouting

Where sand and shale are loose or porous with a small admixture of clay, bore holes may be drilled at intervals and grouted with cement. The seepage from exposed springs or abandoned deep mines need not be stopped entirely; only the level of water should be raised high enough to bury the contaminating material.[23]

FIG 4—Parallel ridges of spoil-bank material in stripping operations.

FIG 5—Top of spoil-bank material before start of contouring.

Sheet Piling

Another method is to drive sheet piling at right angles to the flow of water and grout the joints in the piling.

Chemical Impregnation

A third method is to use the patented Riedel process[23] of chemical impregnation where sodium silicate and calcium chloride in the presence of a catalyst are forced under pressure into the ground. The pores are filled with the resulting calcium silicate and the salt escapes in solution. Although expensive, it might be used to advantage in contoured ground where a clay blanket and other methods outlined above have not been sufficient.

In addition to the preceding, the Shell Oil Co. has developed recently an emulsion of asphalt in water that may be pumped under low pressure into the ground. Chemicals mixed with the emulsion will cause the asphalt to coalesce, producing a mass impermeable to water.

Field Tests

Resort to the methods outlined should not be made until holes have been drilled at right angles to the flow of water and along the center l .e of maximum flow in order to determine the water table and its slope in various directions. The plane of grouting, sheet piling, or of chemical impregnation can then be determined with some assurance.

Tar

A less expensive method than any of the preceding is to cover the spring or source of seepage with a shallow blanket of sand and gravel whose surface is loose. The surface of this blanket should then be coated with a penetrating application of tar or heavy oil, after which the treated blanket should be buried under additional sand and gravel. This method should be used before contouring is started as otherwise excavation will be necessary to reach the point of application.[24]

Bentonite

The secret of successful contouring is the use of material with a considerable admixture of clay that is bulldozed into place. In the absence of clay, bentonite can be used from the Dakotas at a cost of about $20 per ton, delivered in the Pittsburgh area. The results of permeability tests on such clay-treated soil, shown on Fig 11, suggest that three to four tons per acre of bentonite will produce about the same coefficient of permeability as is obtainable with local clays. The cost of distributing it with fertilizer spreaders and harrowing it in to a depth of 4 to 6 in., using mechanical equipment, should not be great (compare Davis[25] and Turnbull[26]). The U. S. Bureau of Mines has issued a pamphlet[27] that discusses in detail the advantages and limitations of bentonite.

The American Colloid Co. claims that bentonite in the small quantities mentioned above will not retard the growth of vegetation, that the powdered form is preferred, and that the ground should be moistened before applying.

VEGETATIVE COVER

A coal-stripped area contoured in the manner employed by the Sunnyhill Coal Co. can be made to support readily a vegetative cover. By harrowing, fertilizing with lime, seeding with perennial rye grass, and protecting with a temporary mulch of hay, the stripped and restored areas were observed to have a heavy grass cover in less than four weeks.[28]

Peach trees were planted in the spring of 1945 on one of these contoured areas. They survived the following dry summer and in September showed new shoots more than 6 in. long. Toenges[29] reports that poplar, locust, conifers, and walnut needing less care are more commonly planted at a cost of about $20 per acre in 1934 to 1938.

Stripped but uncontoured portions of the watershed of the West Penn Water Co. have remained almost devoid of any vegetative cover since 1932 (16 years). This lack is due to surfaces that consist largely of chunks of sand, shale, coal, coaly shale, and occasionally limestone, all in a more or less unweathered condition. The progressive weathering, in addition, of the pyrite in the coal and shale on the surface results in an acid condition that is not conducive to the growth of most forms of vegetation. The steepness of the slopes of the uncontoured spoil banks also retards the growth of vegetation.

Toenges[30] has noted that in the glaciated regions of the Middle West, where uncontoured spoil banks contain much weathered glacial debris, vegeta-

tion takes root much more quickly. He suggests that for agricultural purposes, exclusive of orchards, the ridges of spoil banks should be leveled off. He places the cost for this leveling at $50 to $60 per acre.

The method of contouring employed by the Sunnyhill Coal Co. not only levels off the ridges and valleys of the spoil-bank area, but smooths the entire land surface into natural runoff slopes with no undrained depressions. The last cut, where a highwall is left intact, is completely filled in so as to leave no visible trace of the position of the highwall. The selective distribution of harrowed sand, shale, and clay, with the addition of humus, results in a surface that will readily support grass and timber. This entire process of restoration was estimated to cost approximately $250 per acre.

Conflict of opinion exists as to the effect of contouring on growth of vegetation. Without contouring there was in this case negligible growth of vegetation; with contouring marked growth of vegetation was obtained.

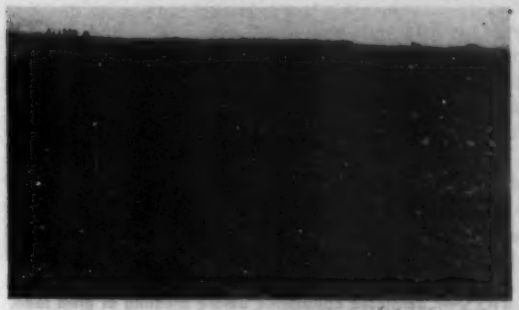

FIG 6—Top of spoil-bank material after some contouring has been done.

FIG 7—Contouring completed showing small peach trees at left.

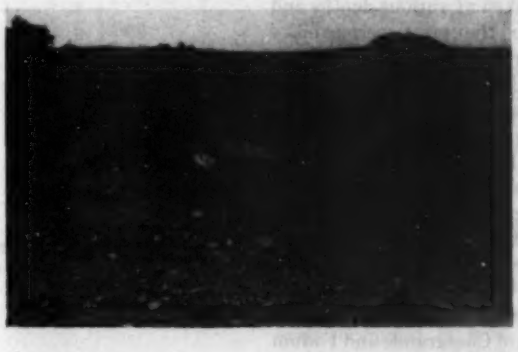

FIG 8—Contouring in progress showing bottom of last cut covered in.

Size Distribution of Contoured Spoil-bank Material

The surface of a contoured spoil bank consists of a mixture which ranges from very fine clay up to stones a few inches across. The percentage composition of these particles determines the relative density of the mixture. Since almost all the material on the surface of a contoured spoil bank is made up of particles less than 2 in. in diameter, the results of mechanical analyses (distribution of particle sizes) may be readily compared with the equation $p = \frac{(d)^{0.33}}{(D)}$, where p is per cent finer, d is the size of the particle, and D is the size of the largest particle. This equation is the curve representing a fine grading with maximum density of mixture for aggregates having a maximum size from 1 to 2 in., as presented by A. N. Talbot and F. E. Richart.[21]

The mechanical-analysis tests were conducted in accordance with the specifications of the ASTM, Method D 421-39 for the preparation of the sample and Method D 422-39 for the mechanical analyses of the soil samples. The results of these tests are graphically shown in Fig 12 to 15, and are compared with the curve for a fine grading with maximum density of mixture for aggregates having a maximum dimension of 2 in.

Tests discussed above and below were run by Mr. F. Bromilow of the University of Pittsburgh.

Permeability of Contoured Spoil-bank Material

There appears to be a complete dearth of any literature bearing on the permeability of both undisturbed and contoured spoil-pile material. Various investigators have shown conclusively that in soils there is a progressive decrease in permeability, and conversely an increase in moisture content, with increase in depth.

A representative set of surface samples of undisturbed topsoil, undisturbed spoil-pile material, and contoured spoil-pile material were collected at random from various properties of the Sunny-

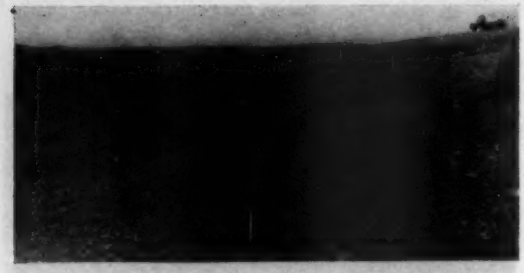

FIG 9—Completed contouring before planting of grass seed.

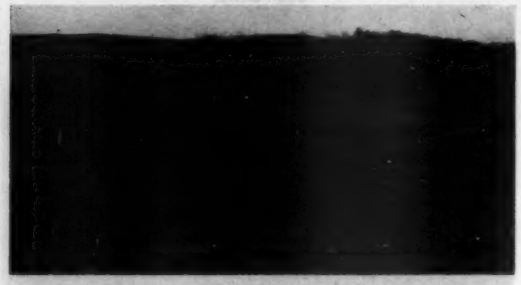

FIG 10—Another completed contouring before planting of grass seed.

"impervious soils." This is the type of material that the Sunnyhill Coal Co. bulldozed from the highwall, spread, and compacted over the bone and waste-coal material placed in the bottoms of successive cuts. Nos. 5, 6, and 7 represent undisturbed spoil-pile material. No. 7 is the only one of the three falling within the range of "impervious soils." The samples obtained from contoured spoil-pile material are Nos. 8, 9, 10, 11, 12, 13, 14, and 15. All these samples, except No. 8, fall within the range of "impervious soils." Sample No. 8 was taken at a point directly above the only bad-surface seep of water coming from any of the area contoured. Further work by way of grouting, chemical impregnation, or other treatment will be necessary to remedy this situation.

In an effort to determine whether the impervious character of the topmost 6 in. of a contoured spoil pile is merely a surface phenomenon, samples of undisturbed spoil-pile material were then taken at various depths. This sampling was by drilling several auger holes, 4 in.

hill Coal Co. These samples were tested for coefficient of permeability in accord with the methods of Casagrande and Fadum.[21] Subsurface samples, in addition, were taken at various depths and subjected to the same permeability tests. The results of these tests are shown in Table 1.

Surface samples were obtained in steel-pipe cylinders 6 in. in diameter and 6 in. in length, in accord with the recommended method of Hvorslev.[22] The "Falling Head Permeator" method of testing was employed in accordance with the recommendation of Casagrande and Fadum.[21] The results of these tests superimposed on the soil classification of Casagrande and Fadum are shown in Table 1.

The permeabilities of gravel, sand, silt, and clay are given in terms of a coefficient of permeability, which is expressed by Darcy's empirical law:

$$Q = k \cdot i \cdot A \cdot t$$

Q is the total quantity of water flowing through a material of cross sectional area, A, under a hydraulic gradient, i, in time, t. The coefficient, k, called the coefficient of permeability, is dependent not only on the size, shape, and structure of the particles, but also on the void ratio and temperature.

Nos. 1, 2, 3, and 4, of Table 1, represent samples of undisturbed topsoil, all of which fall well within the range of

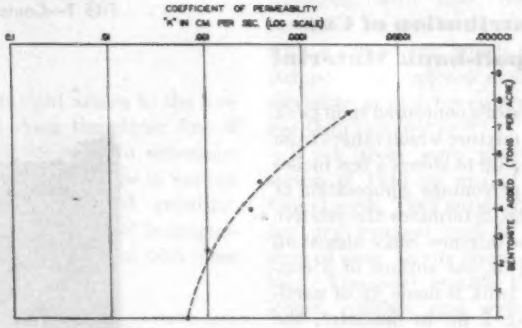

FIG 11—Decrease in *permeability* of *spoil-pile material* to which *bentonite* has been added.

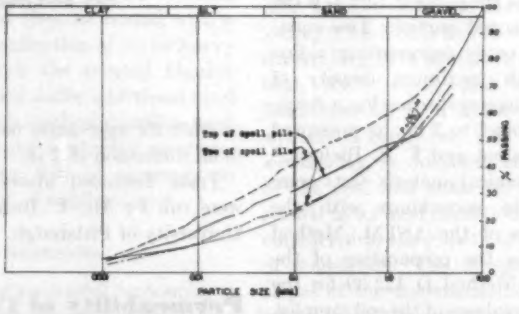

FIG 12—Percentage composition of *contoured spoil-pile material* compared with curve for fine grading with maximum density of mixture for aggregate having maximum dimension of 2 in., location *A*.

MAY

XUM

Table 1 . . . Results of Permeability Tests Made on Samples of Topsoil and Spoil-pile Material Superimposed on the Soil Classification of Casagrande and Fadum

Coefficient of Permeability "K" in cm per sec (log scale)
100
10
1.0
0.1
0.01
0.001
0.0001
0.00001
0.000001
0.0000001
0.00000001
0.000000001
Application in Earth Dams and Dikes
Pervious Sections of Dams and Dikes
Impervious Sections of Earth Dams and Dikes
Undisturbed topsoil, surface
Undisturbed spoil-piles, surface
Contoured spoil-piles, surface
Bulldozed backfill, subsurface
Types of soil, clean gravel
Clean sands
Clean sand and gravel mixtures
Very fine sands, organic and inorganic silts; mixtures of sand, silt, and clay; glacial till; stratified clay deposits; and so on.
"Impervious" soils, eg, homogeneous clays below zone of weathering
Impervious soils which are modified by the effects of vegetation and weathering
← (K = 0.0014) = 1 in. per hour through 6 in. thickness of water head of 3 in.

Hole 1		Hole 2		Hole 3	
Sample	Depth	Sample	Depth	Sample	Depth
A	2 ft 0 in. lost	E	2 ft 10 in.	G	2 ft 10 in.
B	6 ft 3 in.	F	9 ft 7 in.	H	9 ft 7 in.
C	13 ft 0 in.			I	19 ft 8 in.
D	19 ft 9 in.			J	29 ft 0 in.
				K	

in diameter. Drilling was interrupted at various depths and samples of undisturbed material obtained by driving steel pipe into the undisturbed material. The pipe was assembled by screwing a 6-in. nipple, 2¼ in. in diameter, to the lower end of a 5-ft length of 2-in. pipe. Additional 5-ft joints of pipe were added as the depths of the holes increased. The individual 6-in. nipples in which the samples were taken, thus, served as the containers for the laboratory tests for permeability. The open ends of the containers were tightly wrapped in canvas and sealed with paraffin immediately after the samples were lifted out of the hole.

The results of permeability tests run on samples taken at variable depths show that, with the exception of sample *B*, Table 1, all samples fall well within the coefficient of permeability range of "impervious sections of earth dams and dikes."

These results suggest that there is a rapid increase in impermeability of contoured spoil-pile material within the topmost 2 ft. There is, likewise, a progressive impermeability gradient with depth. The abrupt increase in impermeability within a few feet of the surface is explained partly by the filtering out of the fine suspended particles carried through with the first water to fall on the contoured spoil pile. Bulldozing, weight of the overburden, and filtering of fine suspended particles combine to make a contoured spoil pile an effective seal over the pyrite-containing rock underneath.

Meteorological Factors

The role of meteorological factors in the oxidation of sulphur-bearing minerals, occurring in both uncontoured and contoured spoil banks, is frequently overemphasized. The climatic factors that must be considered in the matter of air (oxygen) exchange and resultant oxidation of pyrite are rainfall, temperature, barometric pressure, and wind. Some of these factors are continuously operative while others are only intermittent in their effects.

RAINFALL

Rainfall may run off, infiltrate, or evaporate, and frequently does all three. Romell[24] estimates, however, that rainfall accounts for only one-twelfth to one-sixteenth of the normal aeration of soils.

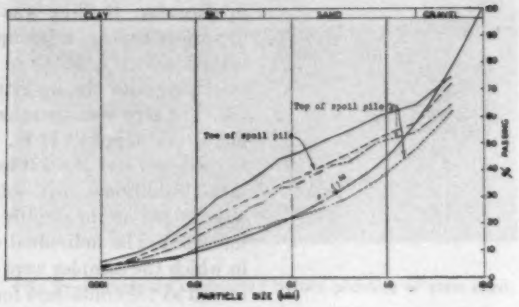

FIG 13—Percentage composition of *contoured spoil-pile material* compared with curve for fine grading with maximum density of mixture for aggregate having maximum dimension of 2 in., location *B*.

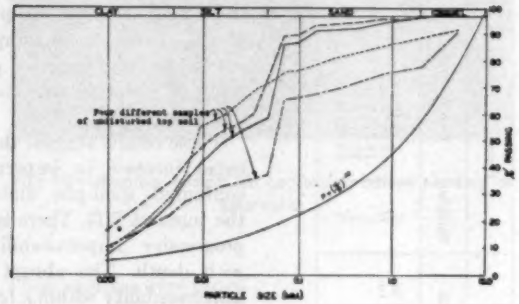

FIG 14—Percentage composition of *undisturbed topsoil material* compared with curve for fine grading with maximum density of mixture for aggregate having maximum dimension of 2 in., various locations.

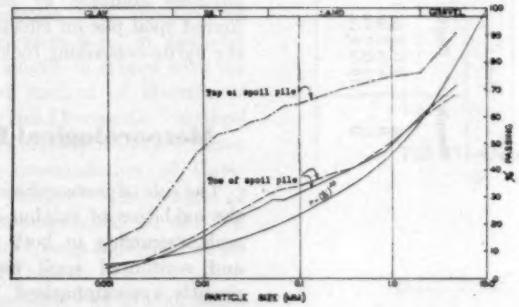

FIG 15—Percentage composition of *contoured spoil-pile material* compared with curve for fine grading with maximum density of mixture for aggregate having maximum dimension of 2 in., location *C*.

Rain Gauges

Accurate rainfall data should be obtained by observing well-known rules in the location of gauges. More than one gauge is desirable for slopes as short as 150 to 600 ft. A gauge to record intensity of rainfall is also desirable. Gauges only 1500 ft apart have shown differences of 5 pct in monthly totals with greater discrepancies on single storms or thunder storms.

A gauge generally should not be located at the crest of a ravine or in the lee of a ridge at right angles to the direction of rain-bearing winds which are east or southeast to southwest for northeastern United States. Errors will be caused by air currents in ravines running north and south, eddies with vertical or horizontal axes, adjacent trees, fences, or slopes. Gauges should be placed at least 100 ft away from steep slopes as otherwise the error introduced could be as much as 15 pct. Gauges should be vertical since an inclination of 15° means an error of 3.4 pct. Errors of course can be cumulative (see Flinn, Weston, and Bogert,[35] Horton,[36] and Mead.[37])

Runoff Measurements

A portable weir is unsatisfactory for runoff measurements because the small drainage area involved cannot be measured with sufficient exactness, and the water backing up behind it will seep underneath. Depending on the slope of the ground, the minimum drainage area tested should be from one to several acres. The weir should be substantially built and the upstream side should have a blanket of clay to prevent seepage loss.

Factors in Runoff

Runoff is reduced by surface irregularities, dense vegetation, surface mulches, and inversely, by degree of slope. Some army engineers use the comparative factors for runoff given in Table 2.

Table 2 . . . Estimated Runoff from Various Surfaces

	Per Cent
Asphalt pavement (good)	85 to 90
Concrete pavements with filled joints	75 to 85
Compacted bare ground	*60 to 65
Cultivated ground	*40 to 50
Thin sod cover	*30 to 40
Anchored mulch (2 tons per acre)	*10 to 20
Dense sod cover	*5 to 10

* Depends on degree of slope, character of surface, and sub-soil (see Morrish,[38] Babbitt,[39] Metcalf and Eddy,[40] Meinzer,[41] Mead,[42] and von Schon.[43]

Mead[44] says an area with clay soil will discharge much more than a district with sandy soil. Discharge from more rolling and less sandy land is estimated at 50 pct more than from flat, alluvial land, but for clay soils the quantity is doubled, and for slope tripled as compared with flat land in determining flood runoff. Meyer[45] says also that clay soils facilitate runoff by capillary action bringing moisture to the surface for evaporation, that the steeper the slope of a watershed, the greater the runoff, and that swamps and marshes, while tending to retard

and equalize ordinary runoff, greatly reduce the quantity of water reaching streams (compare Hardenbergh[46]).

Contouring in strip mining puts clay on the surface, increases the general slope by eliminating depressions, and thus increases surface runoff.

Surface and topographic conditions determine the time available for infiltration. The longer the infiltration, the less the runoff. One test showed that the runoff percentage increased up to 10 min on bare land and up to 50 min on forested land. Increase of porosity vertically and increase in organic matter mean greater infiltration and less runoff (Meinzer,[47] Neal,[48] and Musgrave[49]). Contouring in strip mining decreases porosity and thus increases surface runoff.

During the period when tests were being made to determine the relative merits of contouring as carried out by the Sunnyhill Coal Co., there was little rain; hence significant data in this area are lacking.

Amount of Ground Water

A continuous series of runoff tests were made at Chartiers Creek from 1921 to 1933.[50] It has an approximate drainage area of 260 square miles and is located in Washington County, Pa., approximately 15 miles southeast of the West Penn watershed. During this period of 13 years, the average annual precipitation was 39.5 in. and the average runoff was 17.7 in. Thus, an average of 44.8 pct of the precipitation falling on this drainage area became runoff (surface and ground). The rock strata in this area comprise a typical "coal measures" section and the soil is mantled with a vegetative cover.

The preceding surface and ground runoff of about 45 pct is proof that the ground runoff for such an area as the West Penn watershed is much less. Data on this point are confirmed by Hoyt,[51] Meinzer,[52] and Carpenter.[7]

Crichton[3] concludes that probably not over 25 pct of the rainfall appears as mine drainage or ground runoff in deep mining. Contouring, with its striving for steep surface and highly impermeable slopes, is an attempt to decrease the amount of ground runoff by increasing the surface runoff.

This approach of the Sunnyhill Coal Co. is supported by the following comment:

Reduction in acid mine drainage from deep mines by sealing to reduce ground runoff has been studied by the U. S. Public Health Service.[39] It found for 100 sealed mines in West Virginia that the total acid discharged was reduced about 50 pct in a few months after sealing and about 80 pct in 4 years. Such reduction, significantly, was obtained mainly by reducing the flow of drainage water or ground runoff from the mines by about 70 pct at the end of 4 years.

Infiltration

The infiltration factor is the amount of water the ground absorbs in its pores. This amount can be so great after a long, dry spell and with a light rain or a short, intense thunderstorm as to reduce the runoff to negligible proportions (compare Neal[48]). That portion of the rainfall which percolates down through the voids of a contoured spoil bank is dependent upon the number and size of the pores, the amount of rainfall, the nature of the vegetative cover, and the angularity of the surface slope. Some of this moisture returns to the surface as seeps along the lateral margin of the spoil bank, but as time progresses, the volume of seepage should decrease. Some of this soaked-in water adheres hygroscopically to the surface of soil particles. Small quantities undoubtedly become water of crystallization on various minerals. A part returns to the surface through capillary action and escapes to the atmosphere by evaporation. The surface tension of water for the enclosing surfaces of minute voids is such that this water never escapes. In fine textured soils under conditions of compaction, such as characterizes much of the material of contoured spoil banks, a marked decrease in the number and size of such pores due to water content is an extremely effective factor in retarding the rate of air exchange; oxidation is thereby reduced.

Baver[53] says, "Infiltration of rainfall into the soil may cause a renewal of soil air in two ways, namely, the displacement of air in the pores by the water, which is subsequently displaced again with air, and the carrying in of dissolved oxygen in the water."

A contoured spoil bank is composed of compacted material containing a sufficiently high percentage of fine materials (discussed under "Effects of Diffusion") to prevent any such great exchange of soil air. A considerable amount of entrapped air remains which is not forced out by infiltered water. What little renewal of air does occur as a result of infiltration is governed by the periodicity of the rainfall and the permeability of the soil material.

The amount of dissolved oxygen in infiltered water is relatively insignificant from the standpoint of oxidation of pyrite in a spoil bank. According to Steel[54] the solubility of oxygen in fresh water at 51.8°F is 11.08 ppm and at 60.8°F is 9.95 ppm. These solubilities are maximum values for the temperatures given. Temperature measurements of the ground water in one of the contoured areas of the Sunnyhill Coal Co. range from 52° to 60°F.

Porosity as Affecting Infiltration

Some approximate percentage of porosity variation with different soils will show how the infiltration factor is affected. Dixey[55] furnishes the following data: A collection of perfect spheres of solid matter will have porosity percentages running from about 26 to 48 depending on the size of the spheres. The percentage for clean gravel will be from 32 to 36, for sandy soils from 30 to 35, and for clayey loams about 45. The addition of 3 pct of loam to sand will reduce the porosity of the sand to one-tenth of its former value. A clay will absorb up to 52 pct of its weight in water, but such a mass does not yield water as it is so tightly held by capillarity that little or none of it can escape. Contouring is an attempt to reduce porosity.

Evaporation

A small proportion of rainfall striking the surface of a spoil bank evaporates immediately; the rate is governed by the degree of humidity and the temperature of the atmosphere. During periods of prolonged drought, the surface portions of a contoured spoil bank will gradually give up moisture content. In a humid region, however, this evaporation is merely a shallow surface phenomenon. Contouring will have little effect on evaporation except through the action of vegetation.

TEMPERATURE EFFECTS

Expansion and contraction of the air within the pore spaces of a soil, together with the tendency for warmer air to rise, may cause some exchange of atmosphere. Romell[24] considers temperature differences between the soil and the atmosphere to be responsible for not more than $\frac{1}{640}$ to $\frac{1}{480}$ of normal aeration. Contouring by reducing

porosity will reduce temperature effect.

BAROMETRIC-PRESSURE EFFECTS

An increase or decrease in barometric pressure should result in a small amount of compaction or expansion of the air within the soil, causing a rinsing action, but only if the atmospheric air had penetrated the pores in the upper portion. Barometric pressure changes, however, are so slight over any region as to be of little significance in affecting soil air.[55]

Contouring by compaction reduces the access of air.

WIND EFFECTS

Air in motion and in contact with a land surface will exert a slight suction upon the soil air. The depth effect of this pressure differential would be a small fraction of an inch. Winds of high velocity might exert a slight pressure on soil air. Romell says wind action could not be responsible for more than about $\frac{1}{1000}$ of the normal aeration on vegetated soils (compare Baver[53]). Although this value may be higher for bare, porous, unprotected soils, it is a relatively small part of total aeration.

Contouring by permitting vegetation reduces wind action on the soil.

SUMMARY OF METEOROLOGICAL EFFECTS

Most of the data available indicate that meteorological factors of rainfall, temperature, barometric pressure, and wind are of little consequence in effecting an exchange of soil air. Perhaps one-tenth of normal aeration of soils may be assigned to this combined effect. Contouring in strip mining keeps this effect at a minimum.

Effects of Diffusion

Diffusion as applied to gaseous exchange in soils is by far the most effective means by which the atmospheric gases can aerate soils under normal conditions. It is a continuous process as long as there is any free pore space in the soil. Both compaction and water saturation are operative in contoured spoil banks to decrease the amount of free pore space.

Diffusion can be reduced to almost nothing by 80 pct water saturation. High water-holding capacity of fine textured soils will lower the diffusion coefficient to about one half that of free diffusion. A compacted area at the immediate surface materially restricts diffusion (Baver,[56] Buckingham,[57] and Hannen[58]).

The Ohio River Pollution Survey Report[59] on "Acid Mine Drainage Studies" includes a graphic diagram of the theoretical relationship between oxygen concentration in mine air and the rate of acid formation. The deduction may be drawn from this diagram that a 25 pct reduction in oxygen reduces the relative rate of acid-production reaction 57 pct; a 50 pct reduction in oxygen reduces the reaction rate 87 pct; and a 75 pct reduction in oxygen reduces the reaction rate 98 pct.

These theoretical considerations, when applied to the various factors in the reduction of pore space in contoured spoil banks, lead to the conclusion that diffusion is of little consequence.

Factors Affecting Soap Hardness

WEATHERING

The first effect of contouring is to expose considerable unweathered material so that heavy rains can be expected to wash down considerable mineral matter. This result is shown on one stream where the soap hardness had been as high as 5000 ppm in the summer of 1944 as the result of stripping operations. This value dropped to 700 to 2500 ppm in 1945. The first effect of contouring started in September 1945 was to drive the soap hardness down to about 500 ppm, but a heavy rain drove it up to about 1500 by washing down exposed, unweathered mineral matter.

The great source of aluminum compounds is the feldspars, mica, clays, associated minerals, and numerous phosphates and sulphates.[60] The shales contain aluminum silicates as their most important constituent. Fitch[59] says that the decomposition of these shales, in the presence of pyrite, results in the formation of soluble sulphates that find their way into streams. Another source of alumina in water is the alums. When sulphides of metals oxidize, sulphuric acid is formed and this acts on the aluminous rocks to form aluminum sulphate. The preceding, of course, explains the claim of the water company that the alumina content of its water supply had increased greatly. Such increase was probably due more to disturbance of the surface clay and shales by stripping than to acid mine drainage.

SWAMPS

The record of soap hardness on one stream, where stripping operations without contouring by another coal company had been extensive, showed no increase during June, July, and August 1945, but a heavy rainfall in September caused a marked increase from about 400 to 900 ppm. The flow of water during the summer months had been essentially uniform and substantial. These results follow logically from the large swamp area on this stream above the sampling point. Von Schön[42] has shown the effect of the character of drainage area upon runoff volume. A typical comparison for one condition of ground-storage depletion of water is given in Table 3.

Table 3 . . . Typical Comparison for One Condition of Ground-storage Depletion of Water

Type of Drainage Area	Total Depletion in Ground Storage in Inches of Runoff	Corresponding Monthly Flow in Inches Runoff
Bold relief and in highlands	3.0	0.3
Drift-covered rock and no swamp storage	3.0	0.75
Sandy watershed with large swamp storage	3.0	1.35

We may conclude from the preceding that on this stream the swamp storage acted to assure uniform flow and dilute acid contamination until a heavy rainfall washed in contamination in excess of dilution available (see also Mead[60]).

HIGHLANDS

The record of soap hardness on another stream showed an increase from a March-and-April value of about 700 to about 1500 in June, with no increase in July and August 1945. Rains in September drove it down until a value as low as 250 ppm was reached. This stream had negligible swamp storage and its flow dropped to as little as 1 gpm in August and September. The Sunnyhill Coal Co. was carrying on extensive stripping and contouring operations during 1945 on tributaries in the headwaters of this stream. The lack of increase in the soap hardness during the dry summer months and the drop in amount of soap hardness with increase in rainfall are evidence of the

effectiveness of the contouring. The contrast in results as to soap hardness between this stream and the preceding where there was considerable swamp drainage is significant as to the benefits from contouring.

Dry Weather

Soap-hardness records were kept by the water company on various streams for periods ranging from 4 to 12 months. Samples were taken at intervals ranging from one week to one month. Charts on five of these streams in which the Sunnyhill Coal Co. was interested showed marked increase in soap hardness during the months of June, July, and August 1945. Typical increases in ppm were as follows: 300 to 800, 300 to 700, 200 to 1100, 700 to 1000, and 1200 to 2000. Such increases should have been expected as study of the U. S. Weather Bureau records at four stations east, south, west, and north of the watershed showed the rainfall to be from ½ to 1 in. less per month than the long-term average for each of those three months.

This conclusion has been supported by studies of acidity and dissolved solids in the Allegheny, Monongahela, Youghiogheny, and Delaware Rivers (compare Clarke,[61] Powell,[61] and Dixey.[58]

SPOT SAMPLING

Spot samples are of limited value in determining the mineral content of a stream. After a drought of two or three weeks, soap hardness values will be considerably higher than after a moderate rainfall. A heavy rainfall or a thaw in the spring will wash down mineral matter that will cause an increase for a day or so in the soap hardness, followed by a sharp drop. A slight rainfall of less than a quarter of an inch will usually have little effect unless the ground is frozen. A moderate rainfall of half an inch or so will cause reduction in soap hardness within 24 hr.

The preceding statements are supported by a study of the record of soap hardness for the raw water from the lower reservoir of the water company. In general, the soap hardness dropped when the rainfall exceeded 1 in. in one day, but a fall of ½ in. or less appeared to have little effect except in winter months when the ground was probably frozen. In some cases, between 1937 and when new stripping started in 1941, the soap hardness increased in the spring in spite of considerable rain. This increase was probably due to stratification of water in the reservoir, with the turnover due to warmer weather, and the effect of stripping operations. The relationship between runoff and rainfall at best is complicated as may be shown by reference to Baver[53] and Neal.[48]

CONTAMINATION IN SHEETWASH

The preceding explanations of weathering and effect of dry weather are supported by soap-hardness tests on samples of sheetwash. Samples taken the morning following a severe thunderstorm after a long dry spell showed soap-hardness values of 1000 to 1500 ppm. These values dropped after a storm a few days later to 100 to 300 ppm. Mason and Buswell[64] report in contrast that one test showed the total solids in rain water to be about 30 ppm and the average hardness 3 ppm. The comparative figures for upland surface water were about 100 and 54 ppm, respectively. These values, of course, would vary with the locality where the rain-water and surface-water samples were taken.

The data above suggest that a fairer test of the effectiveness of contouring is the relative change in the amount of alumina and iron oxide in the raw water supply. The immediate result of contouring is to increase the alumina, but as weathering of the final surface slows down the alumina should drop. Probably three years would be necessary to get the maximum drop in alumina. At the same time, the iron oxide in the water should decrease as the contouring becomes effective in reducing the amount of water in contact with the pyrite, marcasite, and similar contaminants in the carbonaceous shale.

EVIDENCE ON EFFECT OF WEATHER

Increased contamination of reservoirs from acid mine drainage was not entirely due to the new stripping operations that began in 1941 as Table 4 from water-company records shows.

An almost straight-line relationship between decreasing yearly rainfall and increasing average soap hardness of the reservoir water was found for the years 1937 to 1939. The yearly rainfall used was the average of the four

Table 4 . . . Effect of Stripping Operations on Contamination of Reservoirs

Year	Values of Soap Hardness, PPM: Low and Month		High and Month		Range in Year, PPM	Yearly Average, PPM	Weather Comments
No stripping since 1932							
1937	74	Jan. May	128	Dec.	54	101	Wet year, about 5 in. above average.
1938	78	Mar. Apr.	204	Dec.	126	135	About average rainfall for year.
1939	120	Feb.	172	Sept.	52	151	Dry year, 4 in. below average.
1940	92	Apr.	188	Nov.	96	135	Wet year, 4 in. above average. For West Va., wettest year since 1937. Note, however, that for 6 mo. of min. rainfall, the total was 2 in. less than average.
New stripping began 1941							
1941	112	Jan.	180	May Nov.	68	151	For Pa., only twice before have lower amounts of precipitation been recorded. For West Va., fifth driest year of record.
1942	92	Mar.	184	Nov.	92	152	For Pa., the outstanding feature was the frequency and extent of flood-producing storms. For West Va., the mean annual precipitation seventh greatest of record.
1943	124	Jan.	270	Dec.	146	192	For Pa., from an unusually wet May and Oct. to the driest Sept. of record. The total precipitation was about 4 in. below normal. For West Va., drought conditions began in the northeastern panhandle division and continued until end of Sept.
1944	156	Mar.	432	Nov.	276	257	For Pa., driest summer since 1932. For West Va., from June through August, drought of unusual severity prevailed.
1945 to end August.	252	Mar.	488	Aug.	236	394	Precipitation in June, July, and August from 0.5 to 1 in. less than average for each month.
Increases	252 − 120 = 132		488 − 204 = 284		276 − 126 = 150	394 − 151 = 243	

Note: Comments on weather conditions taken from Annual Climatological Summary for Pennsylvania and West Virginia of the U. S. Weather Bureau for the various years. Rainfall figures are based on records of four weather-bureau stations that are east, south, west, and north of the watershed in question.

weather-bureau stations mentioned above. Increased rainfall in 1940 reduced the average soap hardness. The conclusion is reasonable, therefore, that dry weather caused the increase of average soap hardness from about 100 to about 150 ppm. This conclusion is in harmony with other studies of the effect of dry weather on hardness of water.

Rainfall in 1941, when the new stripping started, was about the same as in 1939 and the soap hardness was also about the same. Increased rainfall in 1942, about the same as in 1940, kept the soap hardness about as low as in 1939 and 1940. This result suggests that increased contamination was first felt in 1942. But in 1944 with about the same rainfall as in 1940 and 1942, the average soap hardness had doubled.

The preceding indicates that the dry summer of 1945 undoubtedly had marked effect in increasing the average soap hardness for the first eight months of the year to 394 ppm.

ACRES STRIPPED

The water-company's records for soap hardness of its raw water covered for the period 1937 to 1945 inclusive, were based on samples taken from the raw-water pipe in the filter plant and, as indicated later, were probably higher than reasonable due to probable stratification in the lower reservoir during summer and fall months. The maximum soap hardness had increased from 100 to 200 ppm for 1937 to 1941 inclusive to about 500 ppm for the summer of 1945.

The water company claimed that additional strip mining would increase the hardness still further. A chart by years on rectangular coordinates showed the growth of acres stripped and of soap hardness.

The information furnished was plotted on semilog paper to get trends. Then using average, yearly soap-hardness figures in conjunction with acres stripped on log-log paper, it is possible to show that 1000 acres stripped would only develop about 700 ppm of soap hardness. But 1000 acres stripped or 1½ square miles is probably the maximum for the 4½ square miles of watershed involved. Any relationship that exists is at best, of course, very rough as the estimates of acres stripped are not based on detailed surveys. It also erroneously assumes that nothing can be done to reduce contamination.

An even greater error was introduced in neglecting the effect of rainfall on the increasing hardness of the raw water. The months of June, July, and August 1945, for example, showed about 0.5, 1.0, and 0.9 in. respectively, less than the long-term average of four Weather Bureau stations located north, east, south, and west of the watershed.

The preceding suggests that the completion of strip mining on the watershed would not have greatly increased the contamination of the water company's reservoirs. Any relationship existing between acres stripped and soap hardness is obviously so complicated that study of it is only possible on logarithmic paper.

CONTOURING

An example of the effectiveness of contouring is shown by a stream where soap-hardness values in the winter of 1944 to 1945 ranged from 1000 to 5000 ppm. Soap hardness during the summer of 1945, in spite of the dry weather, decreased from 1500 to 1000 ppm and in September was as low as 700 ppm.

An even more impressive example of the improvement from contouring is found on a stream where the soap hardness in the winter of 1944 to 1945 ranged from 1000 to 9000. During the summer months of 1945 it dropped from 7000 to 4000 and by September was down to 1000 to 2000 ppm. The flow on this stream, however, was contaminated by the discharge from an old country mine and by a large spring that had been exposed in a stripping operation. Both flows can be controlled as outlined previously under supplementary pore-sealing methods. Contamination on this stream, therefore, can also be reduced to negligible proportions.

The best example of the benefits of contouring is found on one farm where all stripping operations have been completed and contouring has been effective since the spring of 1945. Soap hardness dropped on one stream from this farm from about 1000 ppm in March and April to 500 in the dry summer months and to about 200 in September. Spoil-bank samples showed soap hardness as high as 5500 ppm in April. Soap hardness did not increase during the dry summer months.

Still another stream from this same farm showed soap hardness ranging between 500 and 800 ppm during the summer months, with no sign of any increase. In September the soap hardness was about 500 ppm and showed little variation with rainfall. The conclusion again is reasonable that contouring reduces the soap hardness values in acid-contaminated streams from several thousand to less than 1000 ppm.

Additional proof of the effectiveness of contouring will be found in the disposal of refuse or garbage in sanitary fills at San Francisco.[65] Refuse fills of 4 ft are covered with 2 ft fills of earth and rock. Test pits dug after ten years showed garbage with very little sign of the decomposition that is possible with air and water. Fruit and vegetables were so fresh that there was little loss in color. Newspapers were readable. Tin cans were bright and without rust. Metal had deteriorated from electrolytic or galvanic action but had no rust.

ERRORS IN TESTS FOR SOAP HARDNESS

Soap hardness is the test that water chemists are likely to use in comparing acid-contaminated waters. It leads, however, to misleading results, particularly where the concentration of contamination is high.

Kean and Gustafson[66] show that the soap hardness is directly proportional to the quantity of acid added to distilled water. The error in the test even for normal waters, according to Mason and Buswell,[67] is 10 pct. Dr. Hale[68] limits the accuracy to 10 to 15 ppm on water below 300 ppm of hardness, but acid-contaminated water can easily run as high as 10,000 ppm. Scott[68] says the American Public Health Association has recommended against the soap-hardness test because of unsatisfactory results. Variation in the amount of calcium and magnesium in different waters and the presence of sodium salts such as sodium sulphate, iron and aluminum salts, free mineral acid, and some forms of silica prevent precision in the soap-hardness test (Solvay Process Co.,[69] Betz and Betz,[70] Suckling,[71] Hoover,[72] and Betz and Betz.[73]

An attempt to compare waters, varying greatly in their contamination, by using the soap-hardness test is certain to be misleading.

METHOD OF NEUTRALIZING ACID-CONTAMINATED WATER

"Standard Methods"[74] requires that any water showing acidity below pH 4.4 shall be neutralized with alkali to methyl orange. Failure to follow this procedure may cause an

error of 10 to 15 pct. For example, a soap-hardness value on unneutralized acid water of 2700 ppm might become 2300 ppm when neutralized to methyl orange. Betz and Betz[70] agree that free mineral acid must be neutralized previous to the soap-hardness test. Acid water, according to Solvay,[69] should be neutral to methyl orange indicator by titration with sodium hydroxide before the soap test.

For acid waters, neutralization with sodium carbonate until phenolphthalein indicator shows pink is not safe; it should be used only on neutral waters.[75] The results of determining total acidity of water with phenolphthalein indicator in the presence of aluminum sulphate or any other salt of a similar type are valueless as the pink color does not appear until an excessive amount of sodium hydroxide has been added; reactions take place slowly.[76]

Acid-contaminated waters contain large amounts of dissolved salts that act as buffers. Hopkins[77] has explained that adding 0.01 N hydrochloric acid to a liter of pure water at pH 7.0 will change the pH to about 5.0. This same amount of acid added to water containing dissolved salts or buffers will cause a pH higher than 5.0. Every substance in the solution will combine with the acid and thus decrease the number of hydrogen ions set free. This buffer action permits the addition of considerable amounts of alkali to acid-contaminated waters without changing the pH value. Such addition of alkali is required in the soap-hardness test. The greater the amount of dissolved material the greater the error in the determination of pH at the end point for neutralization. An attempt, therefore, to compare by soap-hardness values different acid-contaminated waters where free acid has to be neutralized can end only in misleading conclusions.

In spite of the preceding, some chemists have argued for neutralization of acid water to pH of 7. Even greater errors are introduced by this procedure. A study of about 100 comparisons showed a variation in soap hardness from a few per cent to as much as 50 pct. For example, a soap hardness of 7000 ppm might be as low as 4500 ppm if the free acid is neutralized to pH value of 7.

Total hardness should be determined from amounts present of silica, iron, aluminum, calcium, magnesium, and manganese by calculation as $CaCO_3$ instead of by using soap-hardness values.

As will be obvious from the preceding, soap hardness is not a satisfactory method of determining the permanent or sulphate hardness. A comparison of soap hardness and total hardness as $CaCO_3$ shows for several samples reasonable agreement up to about 250 ppm and increasing divergence as the soap hardness increased to 1000 ppm or over. This divergence is increased by free sulphuric acid and other contaminants, the amounts of which will vary greatly in acid mine waters. It makes impossible the fair comparison of acid mine drainage by soap-hardness tests.

Determination of the Amount of Acid Contamination of Raw Water

LOCATION OF NEUTRAL POINT IN WATER

Too much insistence is placed by water chemists on the requirement that satisfactory water for municipal purposes must have a pH of 7 or higher. Morgan[6] has pointed out that some waterworks prefer a slightly acid water (less than pH of 7) as it acts better in coagulating with lime only, provided the amount of acid, hardness, iron, and manganese can be kept within reasonable limits. Such water might be preferable to another of low alkalinity where an alkali and an acid-coagulating salt had to be applied for proper settling action.

The pH of natural waters is likely to range from 7.0 to 8.0, but organic acids may reduce the value to 5.0 and photosynthetic action may raise it to 8.0.[78]

In comparing contaminated water samples, therefore, the neutral point of 7.0 pH is not the correct line of division between a water that should be acceptable and a water that has been injured by acid contamination. The fact that the water in the reservoir had not dropped below a pH of 7.0 for several years until contamination developed is beside the point, as a water at a pH of 6.0 to 6.5 probably would have been about as satisfactory. Note that the water company was using aluminum sulphate as a coagulant for water with a pH of 7 or over, although lime which is much cheaper would have been equally satisfactory with a pH somewhat less than 7 (see Weston[146]).

ACCURACY OF pH DETERMINATIONS

Determinations of pH on acid-contaminated waters should be made electrometrically. Colorimetric determinations are difficult due to the varying color of the water, to the effect of acid in the water on the organic dyes in the color, to change in temperature of sample as taken and when test is made in laboratory, to use of artificial light in laboratory, to personal equation of observer, and to other factors listed in technical literature. Colorimetric methods at best even on normal waters are not closer than 0.2 pH and on acid-contaminated waters the error is frequently much greater.

Numerous sources of error in colorimetric determinations of pH even in waters between 6.6 and 8.0 have been outlined by McCrumb[79] and Dole.[80] Tengco[81] has reported errors from 0.2 to 0.4 pH in comparison of the glass electrode and colorimetric methods on waters ranging from 7.1 to 8.1. The glass electrode, however, may be used on highly colored water.[81] A comparison of pH values for several samples of acid-contaminated water, as determined by two chemists working independently, showed differences in colorimetric values ranging from 0.2 to 1.4 although the glass-electrode values were in close agreement.

Free hydrogen ions that cause change in the value of pH may come not only from free acid as such, but also from acid salts in mine drainage such as the sulphates of calcium, magnesium, iron, and aluminum. The iron and aluminum acid sulphates hydrolyze more readily than calcium and magnesium sulphates and therefore will depress the value of pH more.

Betz and Betz[82] emphasize that particularly in weakly buffered solutions the pH of the indicator may change the pH of the solution. Certain substances such as free chlorine and hypochlorite affect the color produced by the indicator and may cause erratic results. The pH of pure water at 50°F may be 7.2 but at 75°F it is about 7.0, a change showing the error that may be introduced between time of sampling and test.[70,81]

The tabulation below[84] gives an idea of how important errors in the correct determination of pH values become when the amount of acidity involved is a factor.

Change in pH	Approximate Equivalent Change in Acidity
0.1	1.25 Times
0.2	1.60
0.3	2.0
0.6	4.0
0.9	8.0
1.0	10.0

It follows from the preceding that an alkaline water may actually be highly contaminated with sulphate salts and that mine drainage of various degrees of contamination with sulphates of iron and aluminum cannot be safely compared on the basis of pH values.

FREE ACID

Free acid cannot be determined by usual methods with accuracy in the presence of the ferric and aluminum salts that are encountered in considerable quantity in acid-contaminated waters (see "Standard Methods"[85]). Free-acid determinations are possible by electrometric methods and the use of a chart showing grams of hydrogen per 1,000,000 ml (see Steel[86]). On semilog paper, the resulting plot is a straight line. Multiplying the grams of hydrogen corresponding to a given pH by 49 will give the ppm of free sulphuric acid. Similar multipliers are possible for other acids. Note that, based on normal weights, 1 g of hydrogen is equal to 49 g of sulphuric acid. Free sulphuric acid is usually the only important acid content in water contaminated by coal-mine drainage. Comparison of about 20 determinations of free acid by "Standard Methods" as reported by the water company and by colorimetric methods, showed errors in terms of the latter ranging from 15 to 3330 pct. Part of the error may arise from some instability with resulting progressive changes in the acid-contaminated waters, from errors in colorimetric values of pH, and from possible storage of samples overnight in a warm laboratory as compared to temperatures of probably about 50°F when samples were taken.

TOTAL SULPHATES AND TOTAL SOLIDS

Total sulphates is one of the most accurate chemical tests possible in comparing acid-contaminated waters. The method outlined in "Standard Methods,"[87] may be followed safely. Agreement within 2 or 3 pct may be reasonably expected of two chemists working independently. Silica should be eliminated if any appreciable quantity is present as otherwise the value for total sulphates will be too high.

Determinations of total solids should also show agreement within 2 or 3 pct if proper procedure is followed. Note that suspended solids should be included although the amount in most acid-contaminated waters may not be great.

PREFERRED ANALYTICAL BASIS

Instead of analyzing a contaminated water in ppm, it might lead to more informative results to determine the composition of a contaminated water on the basis of percentage of the total salinity.[61] The results will often be interesting as showing that an alkaline water has more contaminants in it as sulphates than an acid water (see Clarke[150]).

EXTENT OF CONTAMINATION

If determination is to be made of the extent of contamination of a reservoir from specified acid mine drainage, the amount must be expressed in pounds per day. It is not sufficient to take water samples and determine their soap hardness. Acid sulphates in ppm when combined with the volume of flow to get pounds per day or some other ratio is a fairer criterion. The discharge should be estimated from recording gauges giving the head at all times on each weir. Analyses of water samples at such frequent intervals as to coincide with marked changes in flow through the weirs will permit an approximate determination of contamination. Even such results must be corrected for the flow from hillsides directly into the reservoir below the points of sampling on the various streams.

TEMPORARY REDUCTION OF CONTAMINATION

Contamination during the interim between strip mining and contouring need not be important. Water should be removed by pumps from the pits at the coal face during stripping operations and thus there is little chance for contamination. What little acid water does escape from mine pools should be neutralized by the coal company before it reaches the reservoir of any water company. This step can be taken easily by bulldozing a small basin where the stream flow can be collected. A small spillway can be installed in an earth dam below the basin. Lime and even soda ash can be added by chemical feeders where the stream flow passes through the spillway. Below the spillway, another basin should be bulldozed so that the treated water will have time to settle out the precipitate formed by the chemicals.

The preceding treatment is too expensive on a large scale and leads to a large volume of sludge that is as difficult to handle as the original acid mine drainage.[11,13] It can be used to advantage, however, until the drainage has been reduced in quantity and strength by cutting off air and water from the contaminating sources.

Operators of strip mines should not overlook the possibility of diversion from one watershed to another of acid mine drainage where the contamination of a water supply is involved. Such diversion, however, does not solve the overall problem of stream pollution.

Factors in the Treatment of Acid-contaminated Raw Water for Domestic and Industrial Purposes

STANDARDS FOR SOFTENED WATER

Water contaminated with acid mine drainage can be made satisfactory for municipal and industrial use. It can be easily softened with lime and soda ash to a hardness of 150 ppm or less. A large portion of the country is using water in excess of 150 ppm hardness.[88]

Total solids of 1000 ppm are acceptable. American Water Works Association[89] points out that "in areas where water of any character is difficult to obtain, public supplies are used in which . . . the above limits (1000 ppm) are materially exceeded. In so far as the effects upon the constant user of such supplies are concerned no adverse conditions are known to ensue." (Compare U. S. Public Health Service,[90] Baylis,[91] and Collins, Lamar and Lohr.[88])

Sulphates as SO_4 are limited by the U. S. Public Health Service[90] and American Water Works Association[89] to 250 ppm, but Baylis[91] rates quality of water on sulphates ranging from 100 to 400 ppm. On the basis of comparative molecular weights, SO_4 at a maximum limit of 250 ppm is equivalent to sodium sulphate (Na_2SO_4) at 370 ppm. Many cities are using

supplies with sulphates ranging from 150 to 500 ppm.[92]

As to industrial use, limitations have been summarized by Lammers.[93] A municipal supply cannot meet all varied industrial demands so it is the custom of industry to put in such special water-treatment equipment as may be needed to make an available municipal supply satisfactory.

LIME AND SODA-ASH SOFTENING

The indicated treatment for acid-contaminated water is neutralization with lime and then the addition of soda ash to get the formation of the soluble sodium sulphate. Such softening can be done very well in a treating plant in which multiple recirculation of sludge, with incoming water and treating chemicals, results in instantaneous reaction for optimum formation of precipitate. Mechanical regulation of flow and direction of water through the plant will send the precipitate to its circulating zone and to its sludge concentrator and also will send the treated water into the clarified water chamber for discharge to the filters. An upflow type of clarifier and softener, therefore, is desirable in which provision is made for recirculating four or five volumes of sludge for each volume of raw water treated. Separation of solids is obtained by change in velocities and in direction of flow. The sludge blanket will not carry over to the filters.

Lime and soda-ash softening of acid-contaminated water has been shown repeatedly to be satisfactory. A few references supporting this statement are Trax,[93] Morgan and Young,[94] Keeler,[95] and Bouson.[96] Lime is the most efficient chemical known for reducing calcium hardness due to bicarbonate without adding any soluble salts to the water, for reaction with magnesium bicarbonates, and for neutralizing acidity.[97] Soda ash is the most economical means of removing the sulphate hardness that will be found in acid-contaminated water[97] (see Carpenter[151]).

EXCESSIVE LIME

Where lime is used in heavy dosages to change the pH of a water the intensity of an odor may be increased. This result can be offset by the use of chloramine which will also aid the action of any carbon used for removal of taste or odor.[98]

USE OF SODIUM ALUMINATE

Improved softening results are obtained in some cases with the use of a small amount of sodium aluminate (Clark and Price,[99] Black, Bardwell, and Graham,[100] Larson and Buswell,[101] and Hopkins[102]). Where the treated water is destined for boiler use, the addition of some sodium aluminate is particularly beneficial in lowering turbidity and increasing the weight of the sludge blanket.[77,100] The consumption of soda ash will be reduced in general about one-third pound for each pound of sodium aluminate. The liquid sodium aluminate will get better results than the dry form. One pound for each 10,000 to 20,000 gal daily will be needed at a cost of about 5½ cents per pound. Deducting the saving on soda ash, the net cost of sodium aluminate will be about 5 cents per pound (see Larson[149]).

USE OF SODIUM SILICATE

Sodium silicates can be used to increase rapidity of settling and extend the pH range over which coagulation gives good flocculation.[103]

USE OF ALUMINUM SILICATE

Aluminum silicates are helpful as an aid to coagulation. Their use is recommended to improve treatment and to reduce carry-over to the filters by increasing the weight of the precipitate and causing the formation of particle sizes that separate more readily from the clarified liquid. They are usually applied at the rate of about 30 lb per 1,000,000 gal and cost about 7½ cents per pound.

USE OF SEPTAPHOSPHATE

If trouble arises from the formation of aluminum hydroxide in the distribution system beyond the filters, an addition of septaphosphate ($Na_7P_7O_{23}$) will prevent such action. It is known as a stabilizer up to 200°F for any iron, calcium, magnesium, and alumina that may be in the water. About 8 lb will be needed per 1,000,000 gal daily at a cost of about 15 cents per pound.

pH VALUES FOR PRECIPITATION

The neutralization of acid in water with lime will bring the pH value up through 6.8 where any alumina should be precipitated. Further addition of lime will raise the pH through 8.2 to 8.4 where iron should be precipitated. The completion of precipitation of both iron and manganese will occur at a pH value of 9.2 to 9.4 (Bouson,[96] and Morgan and Young[94]).

REMOVAL OF ALUMINA

Acid-contaminated water will contain some alumina but there should be no difficulty in removing it when neutralizing the acid with lime (see previous paragraph). If successive additions of lime do not precipitate all the alumina, dolomitic limestone may be added. Its magnesium (about 40 pct) has an affinity for alumina and reverses the process of adding sodium aluminate to water to precipitate magnesium. Note that dolomitic limestone may be about 58 pct calcium as compared with a high-calcium limestone of about 95 pct calcium. The cost of dolomitic limestone and high-calcium lime as quicklime is about the same usually or $10 per ton. The use of dolomitic limestone in the small quantity needed to precipitate any alumina, therefore, will not increase materially the cost involved in neutralizing with lime.

And still further, if the precipitation of alumina continues to offer difficulties, an additional precipitation unit may be used in series with the first.

One manufacturing company in West Virginia, using acid-contaminated water, has had no difficulty in precipitating alumina with caustic soda.

ACID-CONTAMINATED WATER CAN BE HANDLED

The preceding data are supplied as the average water-treatment plant operator, faced with the problem of handling acid-contaminated water, will argue insurmountable difficulties that actually disappear when met with intelligent methods.

STRATIFICATION IN RESERVOIR

The poorest water in these contaminated reservoirs probably occurred in the summer near the bottom. Their maximum depth is about 25 ft. Acid mine water with its high mineral content will have a higher specific gravity than normal water and should sink to the bottom. Lack of dilution from rainfall and drawdown of reservoirs during

the summer should accentuate the bad effects of contamination. Reservoirs that were relatively long and narrow in comparison with their width probably caused short circuiting of contaminated water, from where most of it entered at the surface at opposite ends from the outlet gates, to those gates near the bottom. Relatively soft water, finally, was frequently wasted over the spillways at times of excessive rainfall and probably no attempt was made to draw off the contaminated water from the bottom of the reservoirs. The failure, therefore, to install variable-level, drawoff outlets probably made the contamination of the raw water in the treatment plant worse during summer and fall than it need to have been.

The preceding statements are supported by soap-hardness tests in August on 11 sets of samples from the two reservoirs. Of these sets 6 showed an increase in soap hardness in ppm, as between surface and bottom samples, ranging from 3 to 11 pct. No significant difference was found in the other 5 sets. A definite trend of 5 to 10 pct in increased soap hardness in the bottom samples was found as the point of sampling approached the outlet gates although surface samples showed no significant trend. For stratification in reservoirs, see Turneaure and Russell,[104] Flinn, Weston, and Bogert,[105] and Davis.[106] For increase in iron and manganese, see Wolman and Stegmaier,[107] Engineering News-Record,[108] Hopkins and McCall,[109] and Purcell.[110]

ESTIMATE OF DAMAGES TO WATER COMPANY

The company's first estimate of additional equipment needed to handle the acid-contaminated water was about $40,000 to $45,000 to cover a precipitator, chemical feeders, changes in its filter plant, and connecting piping. The precipitator was to have a capacity of 2,000,000 gal in 24 hr. At least $12,000, necessary to remodel the filter plant, represents obsolescence that should be borne by the water company. Even the entire amount could be regarded as a proper charge against the water company.

The water company's first estimate of additional operating expenses for lime, soda ash, recarbonation, power, and possible additional labor due to the acid-contaminated water was about $75 per 1,000,000 gal to remove 350 ppm of soap hardness. This estimate is reasonable as to amount if no allowance is made for the deterioration of the water company's supply due to causes over which the coal companies had no control. The assumption that the increase in hardness to 500 ppm, as compared with 150 ppm to which the water was to be softened, was due entirely to acid contamination is in error, as previously discussed.

An estimate of the increased operating cost, furthermore, should be based on the average soap hardness over a period of years and not on the peak soap hardness of a dry summer. The last complete year available is the dry year of 1944 when the yearly average was about 260 ppm. The average for the first eight months of 1945, including a dry summer, was about 390 ppm. Fall rains undoubtedly reduced the latter as the rainfall in September was about 10 in. or four times the average, and in November was about 4 in., or 1.6 times the average. Rainfall in October and December 1945 was about normal. The average soap hardness for 1945 undoubtedly was less than 350 ppm. The average soap hardness for the years 1944 and 1945 was probably about 300 ppm.

A previous tabulation has shown that prior to 1941, when the new stripping started, the average soap hardness of the reservoir water was 135 to 150 ppm with wet and dry weather respectively. The coal companies responsibility for contamination on a short-term basis, therefore, does not exceed 300 minus 150 or about 150 ppm.

But 150 ppm is about 43 pct of 350 ppm and 43 pct of $75 per 1,000,000 gal daily is about $32 daily. Based on 1,300,000 gal daily, the responsibility of the coal companies for increased softening costs does not exceed $15,200 yearly. Capitalized at 4 pct, this amount becomes $380,000 plus about $40,000 for new equipment minus about $10,000 for obsolescence in the filter plant or about $410,000 as compared with the payment of the equivalent of about $500,000 to the water company by the coal companies.

The preceding neglects the reduction in contamination that is possible with contouring. This reduction in the sealing of deep mines amounts to about 80 pct in a few years.[111] The residual of 20 pct of 150 ppm is 30 ppm or less than 9 pct of 350 ppm on which $75 per 1,000,000 gal is based. The charge to the coal companies eventually should not exceed about $6.50 per 1,000,000 gal daily or about $3100 yearly on 1,300,000 gal daily. Capitalized at 4 pct, this amount becomes about $80,000 plus $40,000 for equipment less $10,000 for obsolescence or about $110,000.

The proper payment for the coal companies lies between $110,000 and $410,000 and a payment of $300,000 would have been liberal as compared with the actual payment of about $500,000.

The preceding analysis, however, is still in error. It assumes the continued contamination by strip mining, improper control of drawoff in the reservoir, and drought conditions as during 1943, 1944, and 1945.

The conclusion is reasonable, therefore, that better presentation of the technical questions involved was desirable.

Factors in the Construction of a Water Plant

RESERVOIR CAPACITY

The capacity of any existing reservoirs should be checked to discover silting. Even in humid regions, the loss in capacity can be serious if the reservoir capacity is small compared with the annual runoff. In this case, the annual runoff could be about 1½ ft on 4.5 square miles or about 1,410,000,000 gal as compared with a total storage capacity said to be about 180,000,000 gal in two reservoirs (compare Davis[106]).

SPILLWAY CAPACITY

The spillway of an old reservoir should be checked for capacity against any state or Federal requirements. Old reservoirs often will be found to have inadequate spillways. The cost of increasing the spillway capacity to an adequate amount is a measure of obsolescence (compare Davis,[106] and Flinn, Weston, and Bogert[112]).

A runoff of 6 in. on 4.5 square miles is about 470,000,000 gal, or almost three times the total reservoir capacity, to be discharged in 24 hr—a condition that might easily arise.

FILTER OPERATION

The water company in this case claimed that the softening of the acid-contaminated water had increased the washing time on the filters to 2 hr each for four filters. This condition arose from improper prior treatment, coagulation, and settling of the contaminated water. A modern plant would not re-

quire more than 5 min to wash a filter at the rate of 15 gpm per square foot of area. It is probable that the cost of the excess water used in washing for 2 hr on each of four filters plus power and labor would justify the necessary investment of about $30,000 needed for an additional precipitator and connecting piping.

The filter plant in addition should be equipped with hydraulic valves, loss-of-head gauges, flow controllers, larger wash troughs, new underdrain system, rotary surface washers, and incidental modernizing equipment. Its cost at about $12,000 is a measure of the obsolescence in the treatment plant.

PIPE-LINE CAPACITY

A new supply for a water company usually means a new pipeline of considerable length from the new reservoir to the existing distribution system. The size of this line is frequently set by the rule-of-thumb assumption that a velocity of 2 to 5 fps in it will be satisfactory. This size should be checked to make sure the economic size has been selected based on cost of pumping, plus depreciation and interest charges on the necessary investment (compare Babbitt and Doland,[113] Davis,[114] Cameron,[115] and Reagan.[116]

Uses of Treated Acid-contaminated Water

LOCOMOTIVE BLOWDOWN

Blowdown losses cannot be estimated accurately for locomotives. An increase of 10 pct in water used due to blowdown means increased water and fuel costs that, it is true, can be estimated from data in Kent.[117] Increased blowdown means cleaner tubes, lower maintenance costs, and greater efficiency in burning all fuel so that any fuel lost in blowdown may be offset.

Curtiss[118] has made an intensive study of the value of water treatment to the New York Central Railroad and concludes it is at least 13 cents per pound of incrusting solids. He says that continuous automatic blowdown costs about $18 per month per locomotive but the saving in washout expense is about $36 per month per locomotive.

Locomotives are frequently equipped with continuous blowdown plus manually-operated valve, steam separators, and electric foam-collapsing systems. Blowdown of 10 pct on the main line of a large eastern railroad is desirable with 15 to 20 pct for a smaller road (Hislop,[119] and Williams[120]).

Limit of Total Solids in Feedwater

The amount of blowdown necessary is determined by the limit possible on total solids. If this amount is 1000 ppm and the feedwater has 3000 ppm, then the required blowdown is 33 pct.

The desirable limit for total solids is 3500 ppm for 0 to 300 lb pressure (compare Cassidy,[117] The American Boiler Manufacturers' Association and Affiliated Industries' Fair Practice Committee,[121] and Lammers[92]).

Treatment

Excellent results have been obtained in reducing locomotive-boiler blowdown with organic colloids in feedwater treatment. Concentration of solids from 3400 to 14,000 ppm has been reported with reduction in blowdown from 10 to 1 pct and extension of washing out period from 4 to 10 days (de Frank[122]).

Specially prepared amines and amides are organics that are definite antifoam compounds. They get better results than castor oil. Dissolved solids of 10,000 or more are known and 5000 ppm are common in boiler operation.[120]

Foaming is not usually encountered until the concentration reaches 2100 to 3400 ppm. Castor oil in tannin extract is said to control most cases of foaming. An increase in the concentration of dissolved solids by 75 to 100 pct is claimed.[123] Various types of tannins are also available.[124]

Most types of oil and organic matter will increase foaming.[120] Numerous compounds, however, are available such as cholesterol oils from dried sewage, emulsified castor oil, and various vegetable oils, all of which are more or less effective in control of foam.[125]

No conclusive proof exists that suspended matter is the cause of foaming.[120,125] But certainly filtered water is an advantage as eliminating one possible cause.

One railroad has used sodium aluminate plus organic materials in increasing concentration to 10,000 to 30,000 ppm and reducing blowdown to 2 to 6 pct.[126]

No standard treatment for feedwater is possible but each problem can be solved by the railroad as it develops.[120,127] Terrific concentrations of solids are possible under some conditions without foaming.[120]

The preceding data lead to the conclusion that a filtered water with total solids under the worst conditions not exceeding 1000 ppm, mainly as the soluble salt sodium sulphate, can be handled in locomotive boilers with satisfaction.

Another bug-a-boo that has been raised over the use of an acid-contaminated water which has been softened by lime and soda ash is the content of soluble sodium sulphate.

MEDICAL USE OF SODIUM SULPHATE

Sodium sulphate is also known as Glauber's salt. The latter is sold for laxative purposes and has the chemical formula $Na_2SO_4 \cdot 10\ H_2O$ with molecular weight of about 322. Sodium sulphate (Na_2SO_4) as it occurs in water is without the water of crystallization and has the molecular weight of about 142. The sulphate radicle (SO_4) has the molecular weight of 96.

Merck's Index[128] gives the medicinal dose for Glauber's salt for laxative purposes as 15 g. Fitch[129] recommends for combined salts a dose of 12 g. Assuming a dose of 15 g, the anhydrous sodium sulphate required in a solution of water will be in proportion to the molecular weight or 6.6 g. When sodium sulphate is 1000 ppm, the amount of water necessary to get 6.6 g will be 6600 g. But 1 lb is 453.6 g, and therefore a person would have to drink 14.5 lb of water or 1.75 gal in a very short period.

Fitch[129] says the minimum dose recommended is 1.5 g taken in one large draught of water or say one drinking glass full, as otherwise it will not produce laxative action. But 1.75 gal is equivalent to about 28 drinking glasses. Fitch recommends, therefore, for laxative action a dose of 42 g in 1.75 gal of water. This amount is more than six times the dose obtained when sodium sulphate is 1000 ppm.

In comparison with the large amounts of water mentioned above, note should be made of what a man needs as fluid daily. Sollman[130] claims that from 0.8 to 2.0 liters daily are required and that drinking one liter at each meal is a large amount. McLester[131] places the proper amount at one to two liters daily for the healthy man and says the average adult should take 1.5 to 2 liters daily. In summer and especially in warm climates, these amounts should be increased. Note that one U. S. gallon is equal to about 3.8 liters.

SODIUM SULPHATE IN WATER

Experience with sodium sulphate in drinking water has shown that it is not so objectionable as is often assumed up to concentrations of 1000 ppm (Ellis and Meinzer,[132] Mendenhall, Dole, and Stabler,[133] Suckling,[71] Fitch[129]).

Dixey[134] says that water with 2500 ppm of dissolved salts may be used for many days without serious discomfort, but that water with 3300 to 4000 ppm is used. The immediate consequence of drinking water too high in mineral content is usually diarrhea, but people gradually acquire immunity. Of the various dissolved salts in water, the alkaline sulphates are the least injurious.

Medical testimony also does not support the claim that sodium sulphate is particularly objectionable in water (compare Cushny,[135] and Sollman.[136])

There is no scientific evidence that waters high in mineral content cause kidney trouble or gallstones. Any occasional mild laxative action that such water might cause is an idiosyncracy that should pass quickly with longer use of the water. The taste might be somewhat brackish to the unaccustomed individual.

For some contrary opinions see Boaz,[137] Cohen,[138] Mason and Buswell,[139] Dole,[140] McLester,[131] and Trax.[93]

An acid-contaminated water that has been softened to 150 ppm or less, filtered, and does not contain more than 1000 ppm of dissolved salts as sodium sulphate, in the light of the preceding, cannot be considered an objectionable water.

Physiological Aspects

There is no evidence that hard waters even up to 500 ppm[141] are more or less wholesome than soft waters. Harmful physiological effects from iron, manganese, and aluminum[142] need not be expected up to high concentrations. Amounts retained in filtered water after coagulation are so small that only the most sensitive micromechanical methods will reveal such minerals. No reliable published paper[143] is available that definitely indicates hard water is physiologically harmful. Taste is more important than mineral-salt content but Negus[147] claims that taste is not necessarily harmful. The acid-contaminated water in this case at its extreme of about 500 ppm could be easily softened to 150 ppm or less. The argument, therefore, that a new water supply was necessary physiologically because of hardness falls to the ground.

LIMITS OF SOLIDS FOR CATTLE

Dissolved salts up to 3000 ppm are accepted in Victoria, Australia[144] as safe for working horses, dairy cattle, and pigs. Stock will habitually drink water twice as high in mineralized content[132] as man will accept. Stock has been known to drink water with a sulphate radicle as high as 4800 to 5600 ppm. An acid-contaminated water, therefore, that has been softened to 150 ppm and has 1000 ppm of sodium sulphate should be considered excellent for cattle.

Conclusion

Methods that may be used to reduce acid-mine drainage from strip coal mines include contouring to increase surface run off and such sealing methods as cement grouting, use of sheet piling, chemical impregnation, use of tar blankets, and applications of bentonite. The success of each is based on the theory that any reduction of air and water or either in contact with iron sulphide in the coal or shale will reduce the amount of acid formed.

Meteorological factors such as rainfall, temperature, barometric pressure, wind, and diffusion are of little consequence in connection with contouring in their effect upon the amount of air in contact with iron sulphide. An exchange of air is one of the factors necessary in continuous acid formation.

The hardness of water is increased by dry weather. A swamp will often reduce such hardness by the diluting action of its stored water. An alkaline water can be as objectionable in its sulphate content as an acid water. Acid contamination, therefore, cannot be considered without also studying weather and topographical conditions.

Several of the usual chemical methods for the analysis of water are not satisfactory for acid mine drainage. This statement applies particularly to values of pH, soap hardness, and free-acid determinations. Comparisons of acid mine drainage based on such values will be misleading

Acid mine drainage can be treated to make it satisfactory for domestic and commercial use. The first step is to reduce the quantity of such drainage. The next step is so to draw off from any reservoir the contaminated water that the contamination is reduced. Then various chemicals may be used in a water-softening, filtration plant. Many of these chemicals are not ordinarily used in water-treatment practice.

Damages to a water company from acid-contaminated water should not be assessed without considering losses in value of the water-company's facilities arising from silting of reservoirs, inadequate spillway capacity, excessive pipeline capacity, and obsolescence in any filter plant.

Treated acid-contaminated water can be used satisfactorily for locomotive water supply and domestic purposes with far higher concentration of salts than is commonly supposed. Extravagant standards are sometimes set for a water supply that are not justified by general water-supply conditions or by the competing requirement from industrial growth. The important point is to arrive at such a reasonable balance among conflicting demands as will permit adequate service both to industry and municipalities.

The contouring policy of the Sunnyhill Coal Co. attempted the following: When its operations were completed, the mined area was left looking as attractive as or even more attractive than the natural country when stripping was started. An attempt was made to meet the critics of stripping operations who strongly object to ugly spoil banks and contaminated water (compare Sappenfield[145]). With the low-cost methods now possible with large, modern machinery such as drag lines, stripping shovels, coal-loading shovels, and other motorized equipment such as large trucks, the cost of contouring was not excessive in the case of the Sunnyhill Coal Co.

Pennsylvania has an economic asset in its thin beds of coal that can be mined economically only by stripping. As Toenges and Anderson[146] point out, deep mining recovers only 50 to 60 pct of the coal available whereas strip mining recovers 75 to 95 pct of the coal that otherwise would be a total economic loss.

The methods of the Sunnyhill Coal Co. are worthy of examination where conflict arises between public demands and the requirements of stripping operations.

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Correlation of the Performance Characteristics of Domestic Stoker Coals with Their Chemical and Petrographic Composition

By ROY J. HELFINSTINE* and GILBERT H. CADY,† Member AIME

Introduction

One of the most urgent needs in the field of coal combustion is the ability to predict the performance of a coal from knowledge gained from small-scale tests. Numerous types of analyses and tests are conducted on coal, including the proximate and ultimate analyses, heating value, varieties of sulphur, ash analysis, ash fusion temperatures, free swelling index, petrographic analysis, and Gieseler plasticity. The Illinois Geological Survey has made an intensive study of the value of these tests for judging the performance characteristics of the coal as actually utilized. To date, three reports[1,2,3] have been issued, and another is being prepared. The present paper briefly summarizes some of the results found in the studies.

Equipment

The equipment used for the tests is described in some detail in the above mentioned publications. Briefly, it consisted of a domestic stoker, cast-iron boiler, and water-cooled heat exchanger, which were operated as a forced circulation hot-water system. The entire unit was mounted on scales.

Instruments for recording the performance of the coal included a hot-water meter to indicate the quantity of water flowing through the boiler; a two-pen, mercury-actuated thermometer to record the temperatures of the water entering and leaving the boiler; a chemical-type meter to record the percentage of CO_2 in the stack gases; a pressure gauge to record the static pressure in the stoker-air duct; and a multipoint potentiometer to record the temperatures in the stack and room, and the opacity of the stack gases. A 16 mm motion picture camera was available for taking pictures of either the fuel bed or the scale dial.

White Sulphur Springs Meeting, November 1949.

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[1] References are at the end of the paper.

Procedure

The tests described in this report can be conveniently divided into three phases. For the first phase, a load of 5 or 6 tons of unwashed coal (usually screenings) was obtained from each of fourteen Illinois mines. These coals were all crushed and screened to a size of ¼ in. (square hole) by 8 mesh. Combustion tests were made on a part of this raw, screened coal. Another portion was passed over a concentrating table to reduce the ash to what was considered to be commercially reasonable, and combustion tests were made on this upgraded coal. The ash content of the remaining coal was reduced to a still lower figure by passing it over the washing table with greater reject, or by standard float-sink procedure. This cleaned fraction was then tested in the stoker-boiler unit. Thus three coals with varying ash content were tested from each mine.

For the second phase reported here, coals were obtained from four Arkansas mines and tested as received and after passing over the concentrating table with a normal reject. One Illinois coal was tested in the "washed" condition only.

The third phase included tests on commercially prepared stoker coals

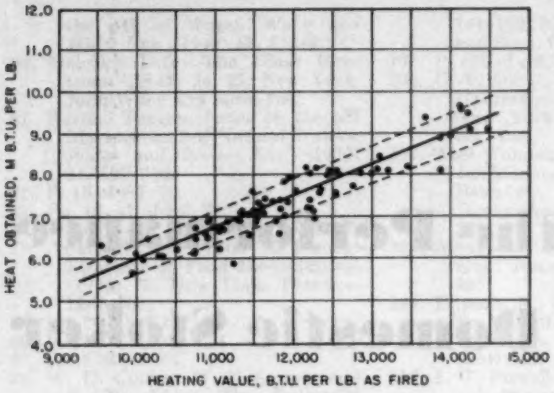

FIG 1—Relationship of heat obtained per pound of coal to heating value, on the as-fired basis.

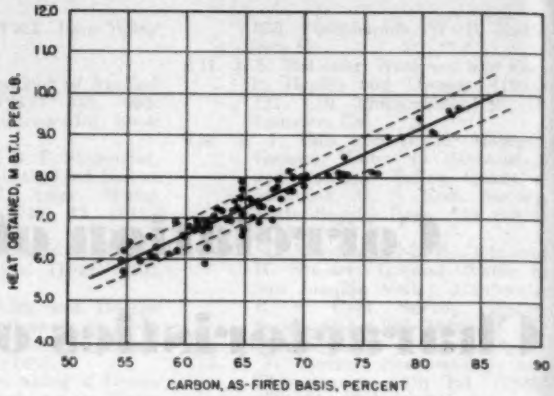

FIG 2—Relationship of heat obtained per pound of coal to percentage of carbon, on the as-fired basis.

from Illinois and several other states and from numerous coal seams. If feasible, they were obtained directly from the mine; if not, they were obtained from a retail coal dealer. There is a possibility of improper identification of the coals obtained in this latter manner, but all reasonable precautions were taken. Table 1 gives information about the source of coals tested in the second and third phase. A previous report[2] gives similar information about the first phase.

The sample obtained is not considered as representative of the seam, or even the unnamed mine. It was obviously impractical, and of no particular importance, to obtain a representative sample for this study. The coals were obtained from a large number of sources in order to have coals of widely varying characteristics.

Table 1 . . . Source of Coals for Second and Third Phase Tests

State	County	Seam
Illinois	Douglas	No. 7
Illinois	Grundy	No. 2
Illinois	Franklin	No. 6
Illinois	Fulton	No. 5
Illinois	Knox	No. 6
Illinois	Grundy	No. 7
Illinois	Christian	No. 6
Illinois	Saline	No. 5
Illinois	Saline	No. 6
Illinois	Randolph	No. 6
Illinois	Jackson	No. 6
Illinois	Bureau	No. 6
Illinois	St. Clair	No. 6
Arkansas	Sebastion	Hartshorne (2 samples)
Arkansas	Johnson	Hartshorne (Spadra)
Arkansas	Logan	Paris
Indiana	Vigo	No. 3
Indiana	Vigo	No. 4
Indiana	Gibson	No. 5
Indiana	Greene	No. 6
Indiana	Greene	No. 7
Indiana	Fountain	Minshall
Indiana	Clay	Brazil block
Kentucky	Harlan	Darby No. 5
Kentucky	Perry	Hazard No. 4
Kentucky	Hopkins	No. 11
Kentucky	Hopkins	No. 6
Kentucky	Letcher	Elkhorn
Missouri	Randolph	Bevier
Missouri	Macon	Mulky
West Virginia	Marion	Pittsburgh
West Virginia	Wyoming	Beckley
West Virginia	McDowell	Pocahontas No. 4
West Virginia	Webster	Sewell
Wyoming	Sheridan	Monarch

Considerable care was used in obtaining a representative sample of the coals as burned, for chemical and petrographic analyses. Standard or proposed methods of the ASTM were used wherever they were applicable.

The petrographic composition was obtained only for the Illinois coals in the first phase. Those listed in this report were made by microscopic examination of closely sized fractions. The analyst considered all vitrain

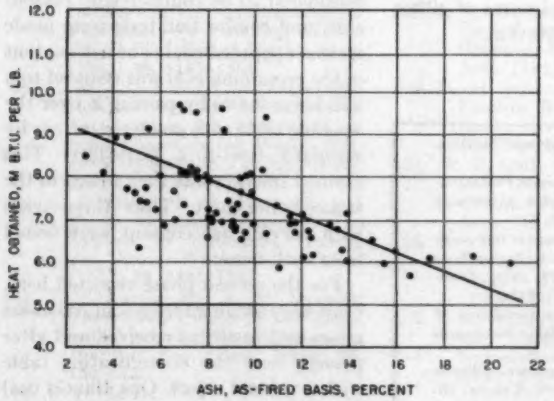

FIG 3—Relationship of heat obtained per pound of coal to percentage of ash, on the as-fired basis.

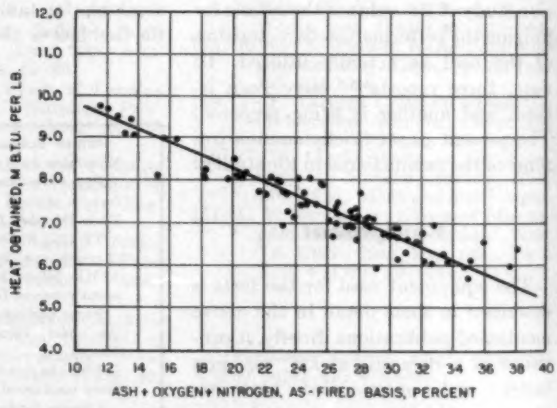

FIG 4—Relationship of heat obtained per pound of coal to the sum of the percentages of ash, oxygen, and nitrogen, on the as-fired basis.

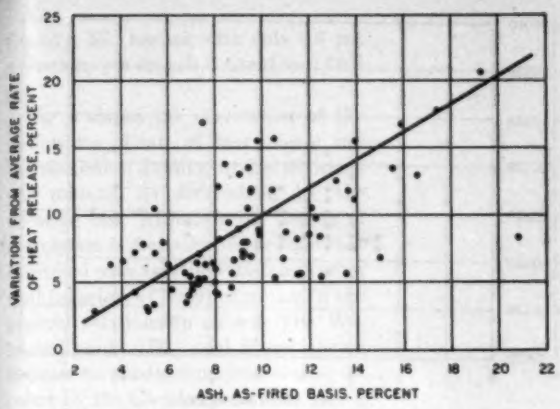

FIG 5—Relationship of the uniformity of rate of heat release to percentage of ash, on the as-fired basis.

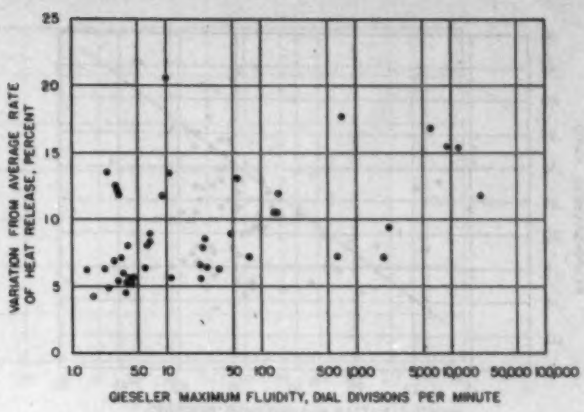

FIG 6—Relationship of the uniformity of rate of heat release to the maximum fluidity, in dial divisions per minute, as determined by the Gieseler test.

bands less than 1/10 in. thick as part of clarain.

The combustion testing schedule included five stoker-operation rates varying from hold-fire to continuous. About 300 lb of coal were burned during each of the operation rates, except hold-fire. No attention was given to the fire during each of these tests with a fixed operation rate.

Combustion Rating Criteria

There are many factors that govern the suitability of coals for domestic stokers. Included are: (1) amount of heat obtained per dollar, (2) attention required by heating plant, (3) ability to maintain the desired temperature in the home, (4) smoke emitted, (5) ability to maintain fire at low rates of operation, (6) cleanliness, (7) the appearance of the fuel bed and fire, (8) the odors given off by clinkers during their removal, (9) quietness of operation, and (10) appearance of the coal. These factors vary in relative importance, depending upon the heating system being used and also upon personal preferences of the operator.

Objective measures of all of these factors would be highly desirable. Unfortunately only the cost of heat can be determined by generally recognized standard tests and this only under arbitrarily fixed conditions. While the cost of heat may be of major importance with large stoker-fired heating plants, it is considered to be of minor importance to many domestic stoker owners.

Some objective criteria of the first five of the factors listed above were devised and determined for all the coals tested. The chief criterion of the attention required is considered to be the quantity of ash, which can be obtained from the proximate analysis. The percentage of ash per million Btu is a more precise measure. Other criteria used were the density and friability of the clinker, and the relative amount of ash removed in the form of clinkers. A subjective clinker rating was also made.

The ability of a heating plant to maintain the desired temperature in a house will depend upon many other factors besides the coal being burned. However, certain performance characteristics of the coal are thought to be influential and were determined for all coals tested. These were the uniformity of heat release, ratio of the minimum and average rates of heat release with

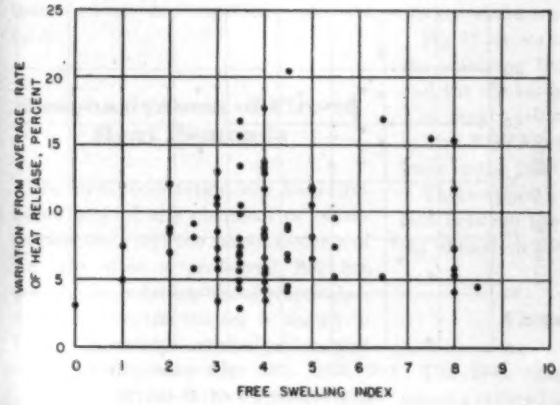

FIG 7—Relationship of the uniformity of rate of heat release to the free swelling index.

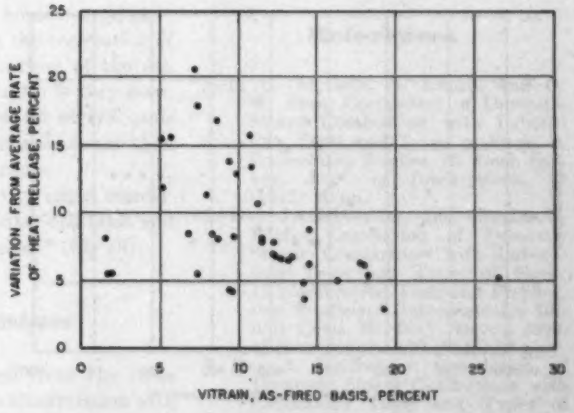

FIG 8—Relationship of the uniformity of rate of heat release to percentage of vitrain.

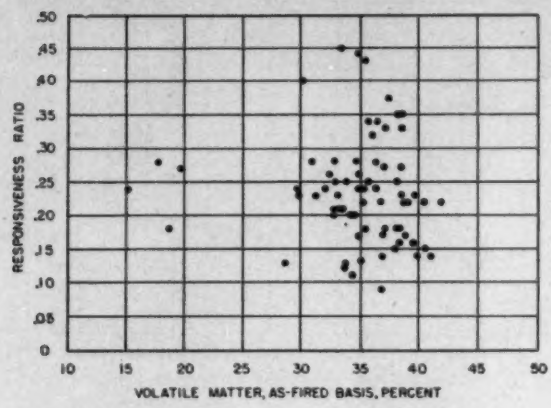

FIG 9—Relationship of the responsiveness of the fire after a prolonged hold-fire period to percentage of volatile matter on the as-fired basis.

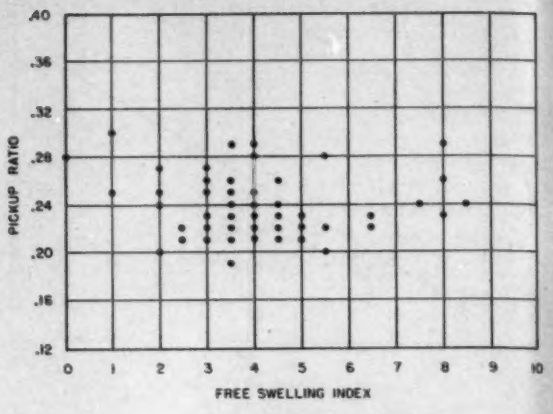

FIG 10—Relationship of the pickup rate after a 45-minute "off" period to the free swelling index.

continuous stoker operation, responsiveness of the fire after a prolonged hold-fire period, the "pickup" after a relatively short "off" period, and the rate of heat output after the stoker shut-off (called "overrun" in this report).

Although no discussion of smoke and hold-fire ability is given in this report, objective data were obtained. Motion pictures were taken of the fuel bed at fixed intervals, and a considerable quantity of colored film showing this action is available for study.

Results

HEAT OBTAINED

The amount of heat obtained from each coal tested was very nearly directly proportional to the heating value of the coal, on the as-fired basis (Fig 1). The solid line appears to be the best single line to represent the points shown. All points falling within the dotted lines are within 5 pct of the value indicated by the solid line.

The heat obtained from the coals tested was also nearly directly proportional to the percentage of carbon as given in the ultimate analysis (Fig 2). Most of the points are within 5 pct of the indicated line.

A fair correlation between the ash and heat obtained was found (Fig 3). This relationship is of particular interest because the percentage of ash is also a criterion of the attention required. Ash is not the sole diluent in coal, and as expected, a better correlation with the sum of noncombustibles was shown (Fig 4).

Numerous other items, and combination of items, gave good correlation with the heat obtained. However, none appear to be as useful as the relationships mentioned, particularly the one with heating value.

Uniformity of Rate of Heat Release

None of the items included in the chemical or petrographic analyses gave a good correlation with the uniformity of rate of heat release. One of the better correlations appeared to be with the percentage of ash (Fig 5). The performance of several coals failed to follow the general trend of increasing variability in rate of heat release with an increase in percentage of ash. One example of nonconformity was the Pittsburgh seam coal from West Virginia which had about 17 pct variation, although its ash content was only 7.5 pct. An unprepared coal from Wabash

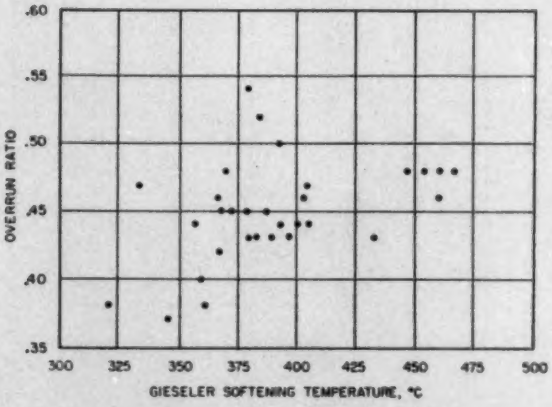

FIG 11—Relationship of the overrun rate after a 15-minute "on" period to the Gieseler softening temperature.

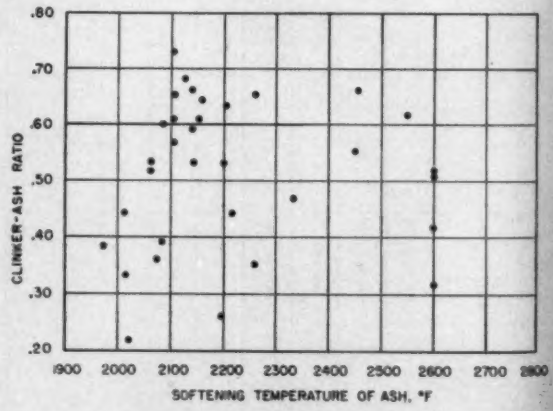

FIG 12—Relationship of the clinker-ash ratio to the softening temperature of the ash.

County, Ill., burned with only 8.3 pct variation, yet its ash content was 20.8 pct.

Fig 6 shows the correlation of the uniformity of rate of heat release and the maximum fluidity, in dial divisions per minute, as determined by the Gieseler test. Although the degree of correlation is probably poorer than that exhibited with ash, the Pittsburgh seam coal (abscissa of 6000) conforms to the general relationship shown. The Wabash County (Ill.) coal is not shown because no plastic properties were indicated by the Gieseler procedure.

The coking characteristics of coals are usually thought to exert considerable influence upon the uniformity of combustion in domestic stokers. One of the best indicators of coking tendency is thought to be the free swelling index. However, Fig 7 shows that the correlation is very low. Five coals with swelling indexes of 8 or greater burned quite uniformly.

The banded ingredients were not determined for all of the coals burned because of lack of suitably trained analysts. Fig 8 shows the relationship between the uniformity of rate of heat release and vitrain for all coals analyzed. The general tendency seems to be for more uniform combustion with the higher vitrain coals. This may be a reflection of ash content, because the coals with higher vitrain usually had lower percentages of ash.

As stated, the percentage of vitrain reported did not include any bands less than 0.1 in. in thickness. The coals with "bright" clarain might have considerably more vitrain than reported, if no limit were placed upon the thickness of the bands. The correlations with the banded ingredients are therefore considered to be incomplete. It is hoped that further investigations can be made.

Responsiveness of Fire to Heat Demands

No useful correlation was found between any of the chemical or petrographic tests and the responsiveness of the fire after a prolonged hold-fire period. The relationship of responsiveness and volatile matter is shown in Fig 9. The widely scattered points were typical of all plots made.

The correlation of the responsiveness of the fire after a 45-min off period (called pickup) with any chemical or petrographic item was likewise poor. Fig 10 shows a typical example.

The rate of heat release after the stoker shut off did not exhibit a useful correlation with any of the chemical or petrographic tests made. A slight tendency for an increase in "overrun" to accompany an increase in the Gieseler softening temperature is shown in Fig 11.

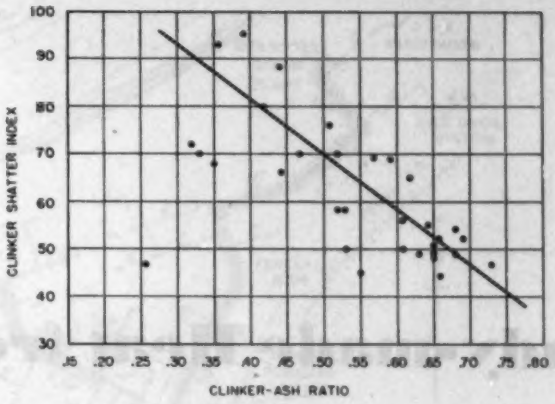

FIG 13—Relationship of the clinker shatter index to the clinker-ash ratio.

Clinker Characteristics

One of the primary requisites of coal for a "clinkering" type stoker is the ability to remove the ash in the form of clinker. This characteristic was indicated as the ratio of the weight of clinker removed during the tests and the total weight of ash formed. The ratio was always less than unity because the tests were started with no ash in the combustion chamber. A bed of loose ash had to be accumulated before clinker was formed. Less than unit values do not mean that all the ash could not be removed in the form of clinker with normal home operation.

Fig 12 shows that the correlation of the softening temperature of the ash and the clinker-ash ratio is very poor. The clinker-ash ratios for several coals in the 2000°F range were lower than some in the 2600°F range.

There appears to be a slight correlation between the clinker-ash ratio and the clinker-shatter index* (Fig 13).

Conclusions

The heat obtained from the coals tested exhibited a good correlation with several items given by chemical analyses. The most useful relationship was with the heating value, on the as-fired basis.

No single item, or combination of items given in chemical or petrographic analyses was found that gave good correlations with any of the other measured combustion characteristics. The percentage of ash, the fluidity of the coal as determined by the Gieseler test, and the percentage of vitrain exhibited a fair correlation with the uniformity of combustion.

The clinker-ash ratio appeared to have a fair correlation with the shattering characteristics of the clinker.

Insufficient space is available to show additional graphs or to discuss the lack of correlation exhibited by more than one hundred combinations of chemical and combustion characteristics that were studied. Little or no useful correlation was exhibited by any except those mentioned in this report.

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* The percentage of clinker by weight that broke into pieces weighing less than ¼ lb after two drops from a height of 6 ft.

Ready-made Heat from Coal

BY D. W. LOUCKS*

There is plenty of evidence to indicate that at least one of man's chief interests in life is to make himself as comfortable as possible. If you doubt this, just watch the fellow next to you for the next half hour trying to find the most comfortable position that a hard chair has to offer. Comfort, however, does not always mean an easy chair. To some, it may mean a wealth of money; to another, freedom from worry. But to most of us, it means first of all a comfortable atmosphere in which to live, and to a great many of us it probably also means freedom from that annoying task of firing the furnace.

Today more than ever before, automatic heat is one improvement that is placed high on everyone's list. Perhaps this is because automatic heating is becoming relatively cheaper. Perhaps it is because of a good publicity campaign on the part of the oil and gas men or maybe it is just that we are getting lazier day by day. At any rate, almost every issue of *Better Homes and Gardens*, *House Beautiful*, or your other favorite home magazine carries an article extolling the virtues of this or that automatic heating system.

If I were to ask you to name the first thing that came to your mind when I said automatic heat, you would probably say either gas furnace or oil burner. Or if you had just been studying heating systems, you might possibly say heat pump. But chances are you would not mention anything about coal, and yet coal is the most common source of the greatest automatic heat of them all. I say this because coal is the fuel used almost universally by the district heating industry in producing and delivering to certain heavily populated areas heat ready to use at the touch of a valve or the click of a thermostat. Although the industry is over a half century old, it has not experienced the widespread development of other utility industries because of certain limitations which I believe you will realize from the next few minutes discussion.

District Heating Operations

We may define district heating as any operation where two or more buildings are heated from a central heating plant. The method of heat transfer may be hot water or in some cases warm air, but generally the medium of heat transfer is steam. So universally is steam used that the industry is frequently referred to as the district steam industry.

The Allegheny County Steam Heating Co. which operates the district heating system in downtown Pittsburgh is a subsidiary of the Duquesne Light Co. Although organized in 1912 primarily as a means of securing the electric load of downtown buildings, the service has now become so valuable and so popular that it is no longer considered a necessary adjunct to the electric business but rather a separate business standing on its own feet.

Fig 1 shows the layout of the plants and distribution system of downtown Pittsburgh. Two generating plants, one known as the Stanwix and the other as Twelfth Street, supply the area. Each has two boilers with capacity totaling 1,350,000 lb per hour. The Stanwix Plant is supplied coal by truck. The coal is pulverized at the plant and burned as powdered fuel. Coal is supplied to the Twelfth Street Plant also by truck but the boilers are stoker fired.

Over 1¼ miles of tunnel house a portion of our main lines, but it requires over twelve miles of pipeline, ranging in size from 32 down to 1 in. in diameter, to supply all our customers. The distribution system consists of two systems in a sense, one high and one low pressure with certain interconnections between the two. Our high pressure system supplies steam up to 125 lb to some but not all customers, while the low pressure system operates in the range of 10 to 20 psi. Note that the two plants are tied together through large steam mains and that the system to some extent is a loop system, making it possible to have a portion of the line shut down without interrupting service to any customer.

Fig 2 conveys a picture of the extent to which steam service is used in the downtown triangle. The black area indicates the buildings which now use district steam. The dotted area indi-

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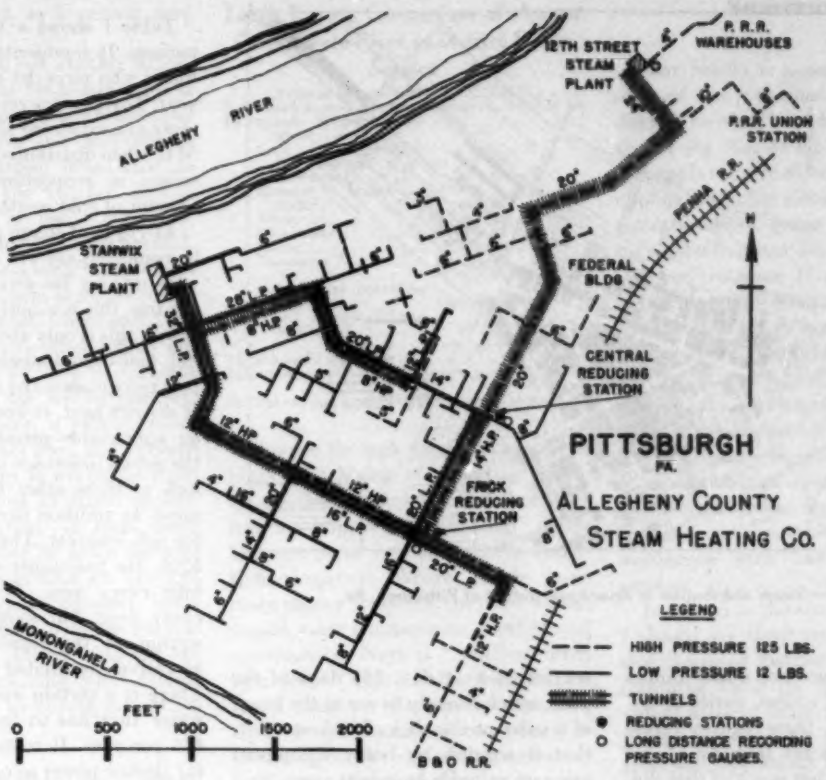

FIG 1—Layout of plants and distribution of system in downtown Pittsburgh, Pa.

cates the vacant land or parking lots, and the white area indicates buildings not yet using service. Note that practically all of the major buildings in the area are supplied, including such as the Oliver Building, Kaufmann's Store, Gulf, Koppers, Grant Buildings, the U. S. Post Office, the City County Building, and many of the smaller buildings and stores. Certain sections are devoid of users. These are areas which have not yet been developed, either because the amount of business to be secured is not sufficient to justify the cost of line extensions or because expansion in other districts has been more promising, and we have not yet developed the other territories.

For many years the downtown has had very little new building, and our growth has developed from existing buildings operating their own plants. Recent talk of new buildings in the downtown area lends encouragement to us as well as many others, and we are confident that such new building development will result in further expansion and growth of the district heating business in Pittsburgh.

Growth of District Heating in Pittsburgh

The Company started in 1912 with six customers, and it has grown slowly but steadily ever since. Last year, we sold approximately 1,450,000,000 lb of steam to 465 customers for which we received revenue amounting to about $1,350,000. To supply that many customers with that much steam requires an investment here in Pittsburgh of over $8,000,000 of which approximately half is in boiler plants and the other half in distribution facilities. Last winter the hourly output reached 850,000 lb of steam which is equivalent to converting 425 tons of water to steam in 1 hr. That is a considerable quantity of steam but when compared to our total generating capacity of 1,350,000 lb per hour, it is easy to see that we still have plenty of spare capacity.

A careful analysis of the foregoing figures will reveal some rather interesting features of the district heating business. For example, a brief calculation will show that the average amount paid us per customer is $3000 per year, and the average net rate per thousand pounds of steam sold is between 93 and 94 cents. Further analysis will indicate that the annual sales of 1,450,000,000 lb of steam is only 20 pct as much steam as the peak load facilities of 850,000 lb per hour are capable of producing. When this 20 pct load factor is compared to one of 65 to 75 pct for the electric utility industry, it is easy to pick out one of the factors that so far has been a handicap to us. We are, as you know, in a seasonal business, largely building heating. What we need is a large summer business to fill in the valley. Several possibilities are constantly being studied by the industry. One is the development of a year-round manufacturing process load. Another is the development of the use of district steam for air conditioning. This latter appears to offer considerable possibilities especially for commercial areas such as we supply where there is little hope of developing much industrial load.

The figures just quoted also reveal that nearly $6 of invested capital is

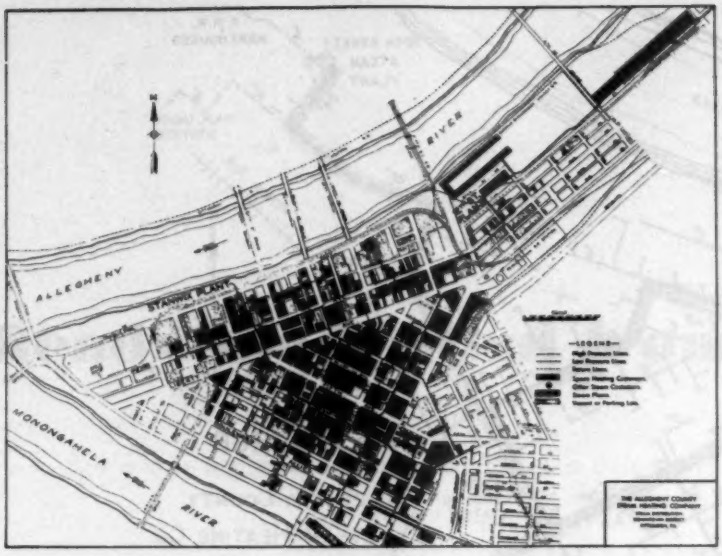

FIG 2—Steam distribution in downtown district of Pittsburgh, Pa.

required to produce one dollar annual revenue. This, of course, varies in different cities but these figures reveal two other significant features of our industry. One is that much of that dollar goes to cover fixed charges on investment which does not vary much over good times and bad; hence, it is possible to maintain a more stable price for the service throughout the business cycle. For example, the only change in our rate since 1932 has been that resulting from a coal clause providing for recovery of the increase in the price of coal used in the plants. The other significant feature is that with a ratio of investment to revenue of 6 to 1 where a high load density area is supplied, it is not difficult to see that as lower load density areas are invaded, either cheaper distribution methods must be found or higher rates must be charged if a 6 to 1 ratio is to be maintained. To do either requires all the skill the men of our industry can muster.

What I have given you is a brief picture of some of the features of district heating from the industry point of view. Now what are some of the features from the customer's point of view.

District Heating from Customer's Viewpoint

If you were a prospect being approached by one of our sales representatives and you were told that there is available to you a complete heating service 24 hr a day, 365 days of the year, which is ready to use at the touch of a valve or the click of a thermostat, that it requires no bulky equipment using up valuable basement space, that you do not have to spend your valuable time looking after it, that you do not even need a stack in the building to install it, that the service is piped into your building at no expense to you, and that the service is metered and you are billed only for the amount of steam you use, your reaction would be only one of two things: either "What are we waiting for" or your suspicion is aroused to the point where you say, "What does it cost?" They are both good questions.

COMPARISON OF COST

Obviously we cannot manufacture ready-made heat and deliver it to your door for the same price that some coal dealer can dump a pile of coal on the sidewalk in front of your shop. So just as there is no comparison in the service rendered in either case, just so there is no similarity between the price of steam service and the price of the coal pile. I believe most of you realize though that coal is not the entire cost when one provides his own heat. A true comparison between the cost of private plant operation and that of district steam should take into consideration all of the other items of expense which are eliminated with the use of such a heating service. What then does a cost comparison look like?

Table 1 shows a typical cost comparison. It represents an average customer who pays, let us say, $3000 per year. This average revenue figure represents annual steam sales of about 2630 M lb when distributed over the heating season in proportion to the normal amount of cold weather.

At 7½ lb of steam per pound of coal, it would require 175 tons of coal if he were making his own steam. At $8½ per ton, this is exactly $1488. In other words, this is only about half the steam bill, and even assuming that the prospect recognizes many of the advantages of district heat, it would still represent an appreciable premium if that were the actual difference in cost. But let us look at these other figures for a moment. In addition to coal, he must pay for ash removal. This is estimated at $200. He has stoker and boiler repair bills every year. Well, perhaps not every year, but over the life of the equipment the repairs may be conservatively estimated at $125 per year. There is a certain amount of makeup water that has to be added. That is $15 per year. It costs him $75 a year for electric power to operate the stoker and to provide the necessary light in his boiler room. Since it is a fair size building, it requires a sizable boiler plant which requires more than casual attendance. Assuming that a man is needed for this purpose only nine months out of the year, labor may be conservatively estimated at $1200. Tbere are also certain additional insurance costs which must be paid. They are estimated at $36 per year. These total up to $3139 a year. But that is not necessarily all. If he is not already at the place where he needs a new boiler, sooner or later he will be. The comparison then is not complete until he includes fixed charges. On an estimated investment of $7500 the fixed charges at 12 pct are $900 per year, and when this is added to the annual operating expense, we find the total annual charges against the plant to be $4039. And when this is compared to a $3000 annual steam bill, there is an annual saving of $1039 in favor of district steam.

But suppose he says, "The boiler is in good shape. My lease has only five more years to run so fixed charges mean nothing to me." So he automatically drops out $900. And suppose he says, "Firing is only an incidental job for my janitor who has a dozen other things to do at the same time. Even if I eliminate the boiler, I could not

eliminate the man so I cannot save $1200.

Thus if he drops out another $1200, in his mind at least his heating cost is $1939 or approximately $1000 less than district steam. Labor and fixed charges are two of the largest items that go towards tipping the balance in our favor. However, in many cases, although labor and fixed charges are real, they may not have a sufficiently direct bearing on the problem to secure recognition by the prospect. Under such conditions, we have a tougher selling job for it is then that we have to convince the prospect that the greater comfort, freedom from worry, a cleaner basement space for other uses, and perhaps several other items is worth far more than the extra cost of steam service over plant operation. In most cases there is usually one or more features about district steam that are particularly attractive to the prospect. Some time ago I went back over the records of the jobs sold during 1946 for the purpose of determining what factors made it possible to arouse interest in our proposition.

FACTORS INFLUENCING PROSPECTIVE CUSTOMERS

Table 2 shows the results of such analysis. We discovered that there were nine major factors which made it possible to get our foot in the door and contributed greatly to successful negotiations. In many instances several of these factors influenced each sale. But in every case we can say that one of these was the major consideration affecting our negotiations. Note that out of the 49 customers sold during the year, "change of ownership or occupancy" was the primary factor in the greatest number of instances. Usually when a property changes hands, the new owner is full of enthusiasm to rehabilitate, improve and dress up the building because he has a new interest and a great ambition to make his newly acquired property outstanding. District steam service fits in perfectly with such a plan, and we emphasize that point in our discussion. Next in importance comes the enforcement of the smoke ordinance. This analysis, by the way, covers the first year after the smoke ordinance really became effective, and obviously it played into our hands to a greater extent than normally that particular year. In fact, it still plays an important part but only where previously satisfactory plants are now failing to comply with the ordinance through deterioration of the plant or relaxing of operating supervision. Next comes the factor of "desire for improved conditions" which becomes more real as business conditions improve. Where people have more money to spend, they are willing to put more emphasis on comfort and convenience. Next is "building being remodeled." This is in line with the first factor that we discussed except that there is no change of occupancy or ownership involved. It is not necessary to discuss all of these factors. You can see the relative importance of the others. I shall comment briefly on "new buildings." Almost without exception, new buildings are rather easy to sell. For when a building is yet in the drawing board stage, it is much easier to eliminate boiler plant investment, to plan the use of basement space, and to save the investment in a stack. This factor is eighth only because there was little new building in the district at that time. Strange as it may seem, but much to the satisfaction of those of you in the coal business, anxiety over fuel supply did not appear to be critical. Apparently there was more confidence in the coal industry's ability to prevent serious trouble than was indicated at times by news items.

Table 1 . . . Comparison of Annual Cost Private Plant vs District Steam Service

(Average size customer—A.C.S.H.C.)

Estimated annual steam requirements, 2630 M Lb		
Estimated private plant costs:		
Coal (175 tons @ $8.50 per ton)	$1,488.00	
Ash removal	200.00	
Repairs to boiler and stoker	125.00	
Water	15.00	
Electricity	75.00	
Labor	1,200.00	
Insurance	36.00	
Total annual operating cost	$3,139.00	
Fixed charges (12 pct of $7,500)	900.00	
Total annual charges		$4,039.00
Estimated annual cost of district steam		3,000.00
Annual saving favor district steam		$1,039.00

Table 2 . . . Relative Importance of Certain Considerations Which Made Possible the Opening of Negotiations Resulting in Sales during 1946, Allegheny County Steam Heating Co.

	Number of Customers Secured
1. Change of ownership or occupance	11
2. Enforcement of smoke ordinance	9
3. Desire for improved conditions	7
4. Building being remodeled	6
5. Original supplier eliminated	5
6. Necessity of boiler replacement or plant difficulty	4
7. Saving in annual operating cost	4
8. New buildings	2
9. Anxiety over fuel supply	1
Total	49

Summary

That briefly is a general picture of some of the problems and features of district heating here in Pittsburgh. I should say that so far as the industry at large is concerned, what applies here applies nearly the same throughout the entire industry. Some of the features may differ in minor detail but generally they are the same. If you were to talk to a great many of the district heating men, I believe they would tell you that the largest single problem facing the industry today is how to expand their systems at a cost which can be justified by the business to be secured, and when I say business secured, I mean not only the magnitude of steam sales but also business secured at a price which from the prospect's point of view is commensurate with the value of the service.

In regard to the size of our industry, I should say there are at present several thousand district heating systems including those for institutions, individual housing projects, and groups of public buildings. Of these, about 275 represent operations of a commercial nature run by utility companies. Of these 275, roughly 50 of the largest do most of the business and from a company membership standpoint, comprise practically the entire support of the National District Heating Association which is an organization for the advancement and promotion of the district heating business. These 50 large companies have a total investment of approximately 186 million dollars. Their sales amount to about 50 billion pounds of steam annually for which they receive roughly 53 million dollars annual revenue from 27,000 customers. It will be of interest to you that these steam sales create a market for some 2½ to 3 million tons of coal a year.

Nearly every large city and many smaller ones in the United States, except in the Southern part of the country, has a district heating system of which New York City is by far the largest. For example, New York sells approximately 15 billion pounds of steam a year to 2300 customers. This is ten times the sales of our Company here in Pittsburgh which sells a billion and a half pounds of steam annually. Next largest is the one in Indianapolis. The third is Detroit; the fourth, Cleveland; and the fifth, Rochester.

Frequently we have persons say to us, "That certainly is an excellent serv-

ice. When are you going to have it available for my home?" Maybe some day we will. In some cities there now is some residential district heating such as Virginia City, Minn., where the entire city uses district steam. There are two systems in use for residential heating near Philadelphia. The advisability of supplying a given territory depends upon a careful analysis of many considerations. Not long ago Battelle Memorial Institute undertook a study for Bituminous Coal Research, Inc., to determine the advisability of using district steam on a broad scale for residential heating. I am not sure that their report is yet completed, but I am informed that their study shows that such projects are advisable only under the most favorable circumstances.

Future Outlook

Now just where does the industry stand today and what does the future appear to hold for it? The business districts of most of the large cities are now fairly well developed although there is considerable room for expansion in the fringe areas of these districts and in some industrial areas. There is also the possibility of developing a greater summer load through the use of steam for summer air conditioning.

Several things have happened in the last few years to improve the status of our industry and perhaps make it possible to expand more rapidly. First, the price which we must charge for the service now compares more favorably with the actual out-of-pocket expense of operating a private plant. Contributing to this condition is the fact that the basement space is now more valuable, investment costs in plant equipment are higher, and operating costs all along the line have increased considerably. All of these tend to boost private plant costs to an all time high. On the other hand, steam service charges have not and very likely will not increase in any such proportion. The reason for this is that a large portion of the selling price is to cover fixed charges on investment which remain practically constant.

The second thing favorable to the industry is a greater appreciation on the customer's part of the benefits of district heating. When business is good and profits more favorable, people spend more for the comforts of life. Since district heat offers many advantages in this direction, it secures a greater acceptance now.

The third factor is a greater consciousness on the part of the people of the community of the civic value of district heat. We have become increasingly conscious of the economic loss due to smoke. Large district heating plants are operated efficiently and smokelessly. The tendency is for small individual plants to be operated inefficiently, and many of them produce large quantities of smoke and dirt. With traffic increasing almost daily, the importance of avoiding traffic congestion takes on a new significance and the elimination of many trucks handling coal to dozens of buildings in congested areas is important.

The last factor that has served to improve the status of the industry is a general improvement in operation. Time always develops new gadgets, new methods, new devices to improve existing systems or ideas. There have been improvements in efficiencies, both of a general nature and particularly in the matter of distribution. I should say also that there has been greater organization of selling efforts to develop new load. We have become more customer minded, so much so that many of the steam companies maintain a department for the sole purpose of helping the customer solve his heating problems and to operate his system in the most economical manner.

There are now four rather distinct fields which offer possibilities for load building. These are: (1) congested business and residential districts, (2) districts of individual family residences and housing projects, (3) grouped industries, and (4) institutions. Congested business districts represent the most favorable field because of the high load density which I have already mentioned. While there are a number of district heating systems supplying detached residences, in many instances the high cost of the distribution system and operating costs compared to the small quantities of heat required make the cost of district heating service high compared with other methods of heat. On the other hand, certain housing projects lend themselves much more favorably to district heating systems because of the higher load density and also because the control of ownership is under one hand. This is not usually true of individual family residences.

Some of you may have read of Peter Cooper Village and Stuyvesant Town in New York City, both projects of the Metropolitan Life Insurance Company's postwar development. Thirty city blocks of tenements and antiquated industrial and commercial structures are being rehabilitated into first class housing facilities for 12,500 families. The New York Steam Corp. will supply their entire steam requirements.

Supplying steam to industries for manufacturing processes and for space heating shows promise for future development. Many industries require large quantities of steam, and where they are advantageously grouped, it is often desirable to purchase steam as well as electric service from the local utility. Institutions such as Carnegie Institute of Technology, Pennsylvania State College, University of Pennsylvania, and others, are examples of district heating in this field. In Pittsburgh we have a rather large district heating operation of an institutional nature in the Bellefield Boiler Plant, which supplies a group of buildings of a noncommercial nature in the Oakland district. They include Carnegie Institute, Cathedral of Learning, Mellon Institute, Presbyterian, and Eye and Ear Hospitals, and perhaps some others. I understand it is a nonprofit venture where each user shares the total expense in proportion to the amount of steam used.

District heating is not peculiar to the United States since there are systems also in Alaska and Canada and in several countries in Europe. England, France, Belgium, Germany, Russia, Czechoslovakia, all have district heating systems.

Now I must admit I have tried to cover a pretty big subject in a limited amount of space. Obviously I could give you only a superficial picture of our small but proud industry. I hope, however, that this will give you a better appreciation of what our industry is and does, what some of its problems are, and most of all how valuable the service is which we render to the public.

Atomic Energy, Taxes, Gold, Discussed at Colorado Mining Association Meeting

REPORTED BY JOHN V. BEALL

Steeped in pageantry built up through many years of gathering the mining folks of Colorado for an annual meeting, the 1949 meeting of the Colorado Mining Association, held in Denver from Jan. 31 through Feb. 2, presented a galaxy of talks covering all phases of the mining industry and its relations with the Federal Government. About 650 people registered for the meeting, representing the larger mining interests, equipment suppliers, government officials, prospectors, and their wives. There were many interesting papers describing metal mining practice, geology of various areas in Colorado, industrial mineral developments, and the economic outlook for the base metals. The traditional Gold and Silver banquet, Sowbelly dinner, and supplier's cocktail party did much to create a warm atmosphere of gayety. Still to be reckoned with, however, were the vital concerns of the mining industry —atomic energy, stock piling, taxation, and gold.

Sumner T. Pike, deputy chairman, Atomic Energy Commission, clarified the picture of raw material supplies for the program at the Gold and Silver banquet and at a press conference. Of interest to the prospector and small operator will be the proposed increase in the period of guaranteed minimum prices for low-grade uranium ores from three to five years; lowering the standard set for the development allowance of fifty cents per pound to include ore containing 0.1 percent U_3O_8; and the acceptance of high-lime ore at the Monticello mill by early summer. With reference to the Caribou mine and the unfortunate publicity hinting that it made the United States independent of outside uranium supplies, Mr. Pike emphasized that this was not true nor was it claimed by the Consolidated Caribou Silver Mines, and that the mine's potentialities as far as uranium is concerned were as yet undetermined. As far as the Jones & Laughlin discoveries north of the Sault in Canada were concerned, he stated that no information was available as exploration was probably held up by winter. To the amateur prospector, Mr. Pike warned that the Geiger counter must be used with extreme caution as the instrument will give an indication where no assay can be obtained. Inexpensive, not too sensitive, counters are best for field work. F. C. Bond and F. R. Gruner described the developments and future use of atomic energy and showed a movie of the Bikini bomb tests at the Tuesday luncheon.

Champions of a free market for gold were present from South Dakota, California, Nevada, and Colorado. U. S. Senator Pat McCarran is fostering a bill that will come up for consideration before the present Congress which will provide for free ownership of gold without license, the right to import and export gold freely, and the sale of gold for whatever price the traffic will bear. According to Senator McCarran's plan, gold will be bought by dollars already in circulation and it will not be used to create new money. J. C. KempvanEe, of the California Gold Committee, brought a message from Don McLaughlin stating that the removal of restrictions on the sale of gold would not be inflationary but would reflect the degree of inflation already taking place. O. H. Griggs, also of California, felt that gold production is needed as it is the basis of sound money. After gold has been put on a free market and the dollar value of gold has stabilized, he favors a revival of gold coinage. Many others talked along similar lines but J. T. Stroehlke, of Colorado, favored the Government's advancing the price of gold to rehabilitate the miners. At the Gold and Silver banquet, Joseph Stagg Lawrence, vice-president of the Empire Trust Co., New York, suggested that although the Government is keenly concerned with the Ameri-

Dr. and Mrs. James Boyd pause for a moment to have their picture taken.

Some of the AIME crowd at the meeting include Mr. and Mrs. Robert Ziegfeld, E. V. Gent, John Sullivan, Robert H. Ramsey, and Mrs. Sullivan. On the right are the Gold and Silver Banquet speakers, Joseph S. Lawrence and Sumner T. Pike.

can standard of living, it is not doing anything to improve the standard of living of the gold miner. He said that he didn't think there was enough gold in the Treasury to redeem dollars at the rate of $35 per oz of gold and suggested that gold be put on a free market to determine the true value of the dollar.

Covering the broad field of tariffs, European Recovery Program, and spending the taxpayer's money to produce minerals abroad, Otto Herres, vice-president of Combined Metals Reduction Co., suggested that President Truman's state of the Union message contained the veiled threat that if industry didn't expand metal production of its own accord, the Government would do it for them. Mr. Herres said, in effect, that far from fostering domestic strategic metal production, the government imposes obstacles in the form of high taxes and possible tariff cuts. On the other hand, we are building up mining abroad with the taxpayer's money and thus creating a potential competitor in world markets. Mr. Herres believes we must build a strong America and keep our spending abroad within our means.

James Boyd spoke on the place of the Bureau of Mines in mineral research at the Wednesday morning session. His remark that manufacturers are becoming increasingly aware of their dependence on the mineral industries as the source of raw materials was particularly encouraging as support from this quarter should be forthcoming. Dr. Boyd said that the job of the Bureau was to supplement research done by private institutions and industry. He outlined the projects that are now being conducted such as the recovery of vanadium from phosphate ore in Wyoming, mining of chromite deposits in west central Montana, the recovery of mica, beryll, spodumene, etc., found in pegmatite dikes in the Black Hills area, and oil shale mining and retorting at Rifle. Conservation of man power by accident prevention, said Dr. Boyd, is as important as the conservation of our natural resources. Since roof falls accounted for 55 per cent of the accidents in coal mines in 1948, the test work on utilizing electronic devices to test the roof is particularly important. Other safety work includes the studies of mechanization hazards, ventilation, and the use of Diesels underground.

At the luncheon on Wednesday, John Sullivan of Battelle pinch hit for Eugene Hardy, Washington editor of *Iron Age*, who was unable to be present. Mr. Sullivan presented some extremely interesting statistics covering the period from 1901 to the present, which showed that American consumption of food per capita did not change through the years. Our consumption of cloth-making fiber has not changed appreciably. However, our income per capita (and these figures were interpolated to the 1935 value of the dollar so that the effect of fluctuating money value was eliminated) has increased steadily. This additional income has been spent on mineral products. Taking steel for an example, in 1900 our consumption was 300 lb per capita whereas in 1947 our consumption of steel was 1200 lb per capita. From these statistics one can readily trace the rise in the American standard of living.

Edward V. Hickey, director of the Office of Production of the National Security Resources Board, described the function of the board at the Sowbelly dinner. He explained how this board, utilizing the knowledge of experts from essential industries, made mobilization plans to go into effect immediately on the declaration of war. These plans are reviewed every ninety days to keep them up to date. Mr. Hickey emphasized that another war would be a blitz war and so our plans must be made complete right now.

The high spot of the meeting was the traditional Gold and Silver Banquet. Besides the guest speakers, who were introduced by Toastmaster Frank A. Wardlaw, Jr., the program included entertainment by the University of Colorado. The Modern Choir and the University Nights Band sang and played sentimental old favorites and sprightly folk music. Bill Bender, of the University faculty, accompanied himself on the guitar singing old mining songs. After the formal program was completed, the 1500 or so in attendance danced to the small hours of the morning. On the following evening the colorful Sowbelly Dinner was held and while the men folk downed pork and beans and listened to a fine program refereed by John W. Valentine, the ladies participated in the Sour Belle Dinner and saw a fashion show. The Colorado Mining Association, the suppliers, and all the hard-working committeemen are to be congratulated for the excellent meeting.

Graduate Study Restricted . . .

Continued from p. 23

bases for guiding future procedures of mineral industry educational practice on the graduate level.

Any conscientious, deserving student usually can secure financial assistance of one kind or another which will enable him to proceed with graduate study and research in the various fields of mineral industry education. This is demonstrated by the percentages of work conducted under grants-in-aid, fellowships, and instructorships. The opportunities are independent of any governmental aid such as G.I. assistance.

Of the institutions reporting on the questionnaire, only one offers graduate training in all fields; one offers work in all areas except one; and two give training in all branches except two. The training in 18 of the schools is restricted or localized to not more than two fields.

At least four of the schools which are well established as undergraduate mineral industry institutions offer no opportunity whatsoever for graduate training. Of the total number of graduate students counted by this questionnaire over 50 per cent (379) are working in four schools, and 75 per cent (571) are enrolled in a total of nine institutions.

Though some schools are specializing in restricted undergraduate and graduate professional fields and, therefore, are not representative, it is apparent that many of the institutions teaching broad phases of mineral industry education at the undergraduate level either are not offering or are not encouraging well-balanced graduate training. It would seem that such schools are deficient in the enterprise of developing mineral industry education. The facts show a marked unbalance of education opportunities for advanced mineral industry professional training, particularly when an additional year of training over an undergraduate level (5-year program) is considered almost a necessity in some of the other professional engineering areas.

Letters to the Editor

More on Stream Pollution

Commenting on our article about stream pollution, in the December M&M, C. E. Heinrichs, of the Virginia Carolina Chemical Corp., writes:

It might readily be inferred from that article that the companies mining phosphate in Florida have been remiss in their responsibility to the general public. In fact, the direct statement is made without reservation that: "High turbidities in the streams receiving this waste have resulted from careless operation of the ponds or from accidental breaks in the impounding walls." It is most unfortunate that, in addition to creating the general impression of lack of awareness, you should have made a direct statement charging the miners with negligence, especially since such a charge and the accompanying implications are not supported by the facts.

It is well known to those engaged in the mining of phosphate in Florida that one considerable item of cost arises out of the building, maintenance, and operation of adequate slime-settling areas for the purpose of preventing undue pollution of streams. The Engineering and Industrial Experiment Station of the University of Florida, at Gainesville, was commissioned two years ago by the phosphate mining companies to investigate conditions in the phosphate field and to make suggestions, if possible, for the further perfection of slime-settling and slime-treatment methods. This program was a progressive act engaged in by the miners on a purely voluntary basis and involves considerable expense. The findings of that experiment station will soon be made public in a lengthy report which will point out, among other things, that the river waters are in some important respects definitely benefited by the use to which river water is put by the phosphate mining companies.

Under the circumstances, it appears that the article does not do full justice to the situation in the Florida phosphate mining area but that, on the other hand, in view of the high regard in which your publication is held, it might actually be interpreted as a direct accusation of carelessness and the failure on the part of this important industry to recognize a public duty. In all fairness it would appear that this impression should be corrected.

[We wish to correct an impression that may erroneously have been created by our paragraphs about the Florida phosphate industry which imply that that industry is *just beginning* to take steps to prevent the pollution of streams by waste water from the washing plants. On the contrary, settling basins have been used for many years and operating companies have taken turbidity samples at critical points along the Peace and Alafia Rivers and their tributaries for fifteen years. Since 1946, that industry has sponsored a fellowship at the Engineering and Industrial Experimentation Station of the University of Florida for the purpose of studying the effect of waste waters from the phosphate processing plants on the receiving streams.—*The Editor.*]

Philatelists, Unite

A. G. Ackermann suggests engineers back up plans for stamps commemorating the industry:

As an ardent philatelist as well as a junior member of the AIME, I have hoped to see a series of commemorative stamps honoring the American engineers. At last there seems to be a possibility that my hope may be realized. Joseph J. Lawlor, Third Assistant Postmaster General, stated in a recent interview on the WNBC Stamp Club of the Air from New York that the Post Office Department is considering plans for a series of stamps for American industries, which would include a stamp for mining and the steel industry.

I suggest that the AIME take action to see that the proposed stamps for mining and the steel industry become an actuality. Members should urge their Congressmen to support the Industrial Series Stamp bill.

XUM

Book Reviews

Books reviewed in these pages, as well as others, may be purchased through I. P. Klein, Book Department of Mining Engineering. *Most books must be ordered from publishers and therefore require additional time for delivery. Government publications should be ordered directly from the bureau concerned. Books are shipped to members of the Institute by the publisher. Members are billed by the Institute. Whenever possible ten per cent discount is allowed for payment within ten days after receipt of bill, when the amount is $2.50 or more. Most of the books reviewed can be consulted at the Engineering Societies Library, 29 West 39th St., New York City, open weekdays, except the principal holidays, from 10 a.m. to 10 p.m.*

Library books may also be borrowed by members in the United States and Canada as explained on p. 618 of the November, 1948, issue of Mining and Metallurgy.

Appraisal of Mineral Properties

Examination and Valuation of Mineral Property. Third Edition. By Roland D. Parks. Addison-Wesley Press, Inc., Cambridge, Mass. 1949. 504 p. $5.

Reviewed by Frederic H. Main

Revision of the second edition of *Mine Examination and Valuation* has resulted in the expansion of subject matter into five major parts. The third edition, under its new title, presents a broad range of valuable material in a refreshingly concise and lucid manner. For those who seek an indispensable aid in the accurate appraisal of mining properties, *Examination and Valuation of Mineral Properties* will be eagerly welcomed. Notable among the new material is a chapter on the valuation of oil property.

Part I is concerned with mine examination. It is noted with considerable satisfaction that professional integrity is weighed as heavily as the other more prosaic duties. The treatment of sampling and ore estimation is thorough and supplemented by actual sampling practices. A discussion of economic considerations is sobering to the examiner who is prone to regard the valuation of a property in terms of existing commodity prices.

Part II is the straightforward application of a dollar value to a mineral property. The explanation is forcefully presented through numerous examples and case histories.

Part III, by Walter L. Whitehead, is an interesting and informative discussion of property rights and valuation factors in oil production.

Part IV is a brief discussion of valuation theorems based upon premises other than Hoskold's formula.

Part V consists of a compilation of tables to assist in the solution of valuation problems.

Appendix A, by Franklin G. Pardee, is a detailed discussion of the "Michigan System of Mine Appraisal" as it specifically relates to iron mining. The fundamental soundness of the system may well be applied to other commodities.

Appendix B is a comprehensive reference bibliography, and a highly desirable feature by itself.

Admittedly, this book is designed as a student text and as such it appears to be highly satisfactory. However, one is struck by a singular quality. In its versatility, the mining engineer, the exploration geologist, or the small mine operator can, with equal vigor, defend it as having been written specifically for him.

How to Become an Executive

Developing Your Executive Ability. By Howard Smith. McGraw-Hill Book Co. 1946. $3.

Reviewed by Esworthy P. Lange

The author, as a member of the faculty of the Dale Carnegie Institute, has been in a position to analyze the fundamental requirements of the executive position as related to business and community life.

The resulting publication is in reality a summation of countless interviews with men of recognized standing in their respective fields. These interviews present a cross-sectional picture of what the reader himself must do if he desires to obtain personal satisfaction in his own chosen field of work, regardless of its nature.

The author attempts to show that no person can hope to really succeed until he has learned to understand and appreciate the problems of those with whom he is associated, both above and below him, and more especially until he has learned to present his own ideas in a clear, logical manner, and in a way that will invite the attention of those whom he is addressing.

The basic foundation of any true executive is the enthusiasm which he brings to his particular job, and correspondingly, his ability to bring forth the same enthusiasm in those junior to him, in order that they may be ready to assume the duties and obligations of his office, when he in turn is offered the opportunity to advance to a position of greater responsibility.

The pointed examples offered in this book should be food for thought for those who have the desire to succeed, but have not as yet found the right track to the top rungs.

The Gold Placers of Montana

Charles J. Lyden of Butte, Mont., has devoted eighteen months to the task of visiting the placers, past and present, of the Treasure State, and the product of his labor is to be found in "The Gold Placers of Montana," issued by Montana's Bureau of Mines and Geology. Detailed data on placer deposits and operations in 31 Montana counties have been combined with 28 maps showing practically every gulch in Montana's mountains. Copies of the 152-page memoir are $1, at the Montana School of Mines, Butte.

Canadian Mining

Some startling figures regarding Canadian mining have just been revealed, via the 1948 "Canadian Mining Handbook." In the data presented can be read a story of the casualties that have befallen many active mining companies. The number of companies operating currently is less than half the number operating two years ago. Since 1946, when the price of gold was cut, gold exploration and prospecting has taken a 74 per cent nose dive. To compensate, in part, for the loss to gold mining, some companies have turned to silver, iron, and nickel. The rest of this story can be obtained for $2 from the Northern Miner Press Ltd., 122 Richmond St., W., Toronto 1, Ont.

Valuable Mathematics Manual

Numerical Calculus. By William E. Milne. Princeton University Press, Princeton, N. J. 1949. 393 p. $3.75.
REVIEWED BY H. W. STRALEY, III

Commonly one finds that he can translate college mathematics into practical problems only with considerable difficulty. It is with this in mind that the author, who is one of America's leading authorities in this field, has approached the numerical calculus.

Although rigor has, at times, been sacrificed for clarity and practical application, it is not treated in a cavalier manner. The book is well adapted to use in a second course, especially in colleges where a stiff mixture of analytical geometry and calculus, with a smattering of high school review, constitute beginning mathematics. One so prepared will be better able to solve problems in engineering and science than if he had passed through a more conventional program.

Several chapters are particularly worthy of praise. The author seeks to reverse a trend away from determinates in early mathematical courses (Chapter I). Approximate solutions (Chapter II) are often neglected by professional mathematicians. The chapters (IX and X) on least square approximations should be of particular value to mineral engineers.

The Numerical Calculus should grace the book shelves of most practitioners in the mineral industries. Not only students and their teachers, but the seasoned research worker will find it a valuable manual and one that he will soon "dog ear" with constant use.

British Manufacturers' Directory

F. B. I. Register of British Manufacturers, 21st Edition. Kelly's Directories, Ltd. and Iliffe & Sons Ltd. 1948-9. 752pp. 42s. Od.

This, the official Year Book and Directory of the Federation of British Industries, contains information about nearly 6000 British manufacturers and their products, within about 1000 pages. A classified "Products & Services" section lists F. B. I. goods and members services under more than 5000 trade headings.

New sources of supply and fresh contacts are essential for expanding business activity, and this book is planned for quick and easy reference. Addresses, telephone numbers, telegraphic addresses, and overseas agents of British manufacturers are given, in what has been termed "an increasingly valuable sales instrument."

Items of Interest

Dynamite Cartridge Diameters—Explosives manufacturers and the Bureau of Mines have tried, for many years, to show the advantages of using dynamite that has a cartridge diameter of at least 1⅛ in. Although the larger diameter cartridges do have many favorable features, several large mining companies still insist on smaller diameter cartridges. Now, a Missouri School of Mines research project has shown that the 1-in. diameter cartridges give adequate breakage with lower powder cost. The study has been published as Bulletin No. 1, Vol. 19, of the School's "Technical Series."

Time, Motion and Money

The manufacturers have no priority on time and method studies, and mine operators can put such studies to profitable use. That's the thesis of "More Profit in Mechanical Mining," by A. W. Bitner and D. R. Mitchell, of Pennsylvania State College. The book, out this month, presents in simple pictorial manner procedures for making time, method and production studies of mechanized mine sections. Study techniques, and the charts used to analyze them, are presented in detail for the benefit of shift bosses, junior engineers, and top management. Order from the College's Mineral Industries Experiment Station, at $3 per copy.

Chilean Coal Mining

What Chilean coal mining needs is more mechanization and less accent on the "many hands make light work" theory, lest competition from foreign coals and oils make the industry extinct. That is the conclusion of seven Bureau of Mines experts whose detailed field research appears in the Department of Interior Bulletin 474, entitled "Coals of Chile." Diagrams, charts, and photographs have been combined with factual data in 106 interesting pages. It's yours for 35¢, from the Superintendent of Documents, U. S. Printing Office, Washington 25, D. C.

NEW TECHNICAL BOOKS
Engineering Societies Library

New books can be borrowed by AIME members in the United States or Canada for a nominal fee. Bibliographies, photostats, microfilm, and translations can also be supplied.

Submarine Geology. By F. P. Shepard. Harper & Brothers, New York, 1948. 348 p., illus., diagrs., charts, maps, tables, 9½ x 6 in., cloth, $6.

Of immediate importance to economic geologists and to students, this volume contains information on submarine canyons, continental shelves and slopes, coral reefs, waves and currents, and shore lines. The economic applications, such as the oil possibilities of continental shelves, are discussed. All of the latest data available are presented, including as much of wartime research as has been made public. It is written in a nontechnical style and is well illustrated.

Textbook of Geomorphology. By P. G. Worcester. 2 ed. D. Van Nostrand Co., Toronto, New York, London, 1948. 584 p., illus., diagrs., maps, tables, 9¼ x 6 in., cloth, $5.25.

Designed for an introductory course, this book states the fundamental principles, gives precise definitions, and describes and illustrates land-forms. The second edition has improved illustrations, clarifies certain principles, corrects minor errors, rearranges some of the material, and now has lists of topographic maps. The work is particularly well illustrated by nearly 400 effective photographs and diagrams.

Oil Shales and Shale Oils. By H. S. Bell. D. Van Nostrand Co., New York, Toronto, London, 1948. 157 p., illus., diagrs., charts, tables, 9¼ x 6 in., $4.

Beginning with geographical distribution and the history of exploitation, this book presents the existing information on the methods and economics of producing oil from shale. The oil shales of the world are discussed. Mining methods, retorting, and refining of oil from the shale are explained. The relative costs of this oil source are tabulated. References from a wide variety of sources are given.

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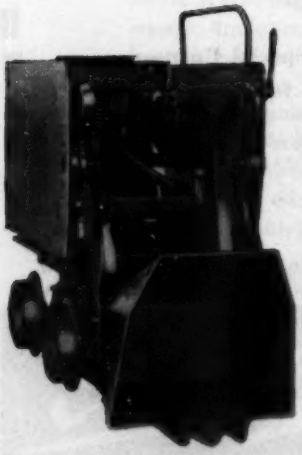

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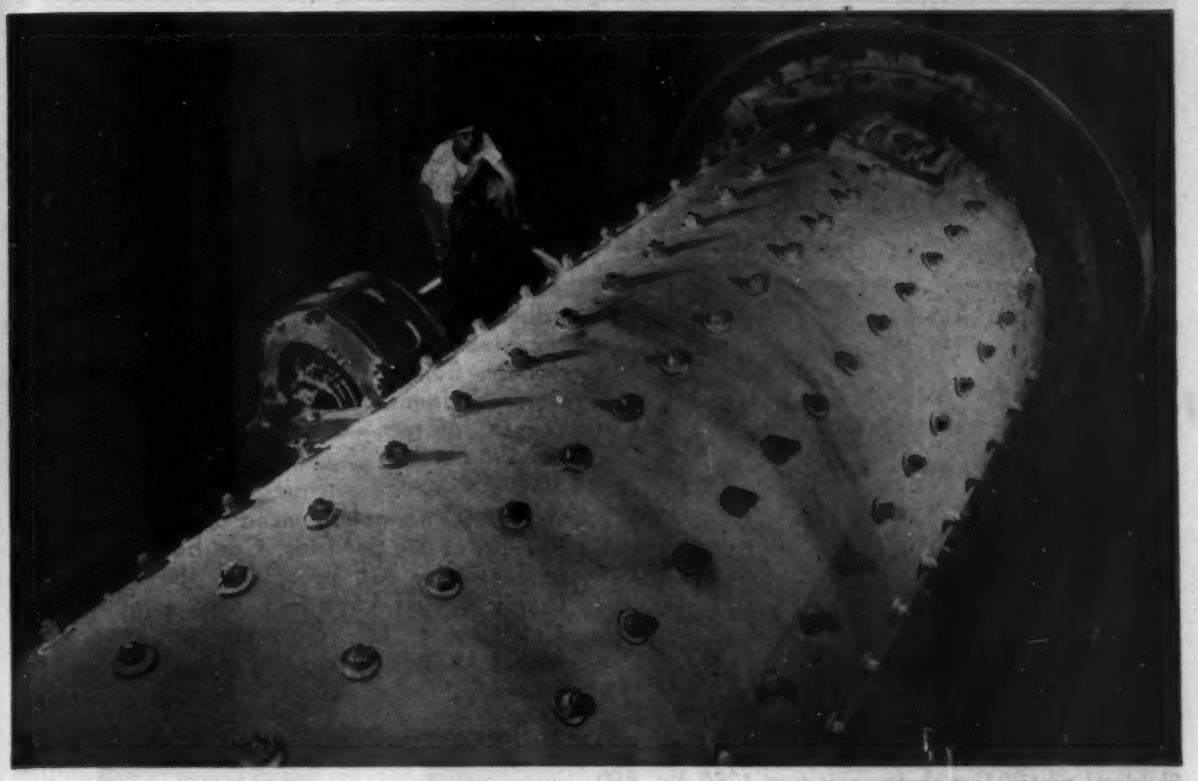

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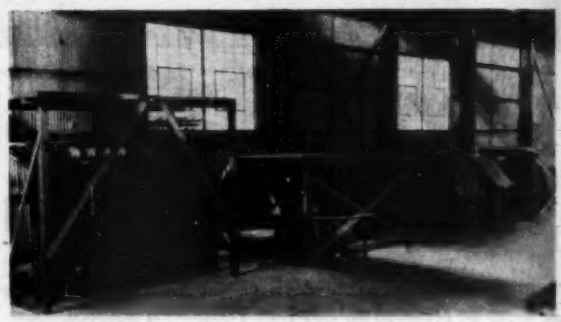

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Government in Your Hair

(*Continued from p. 26, Sect. 1*)

when the land was part of the pioneer West. Now it is the "priceless heritage of the future generations." Don't think for a moment that the Chamber of Commerce proposes doing away with all of the federal lands and putting them in private ownership. We believe in national parks, national forests, etc., within reason, but the trend to continual enlargement must be stopped.

The accompanying map shows the increase of the past decade. Only two states—Alabama and Pennsylvania—showed a decrease, and 10 per cent of Utah's land area fell to federal ownership. Every proposed addition should be examined to see if it is really needed or whether it is just to give some Bureaucrat more land to administer. Figures now show that the Indian Service has one employee for every 38 Indians. All existing federal reservations, particularly acquired lands, should be examined by an impartial board of experts to see if it is serving the purpose for which it is acquired or reserved. If it does not need federal protection, it should pass into private ownership.

tidelands conflict

The biggest invasion of state rights ever attempted by the federal government is its effort to add to the federal domain all the submerged lands along our coasts, from low-water mark to the three mile limit. These lands always belonged to the states and the federal government has only the right to regulate navigation and commerce in the waters above them. Based on the reasoning of the Supreme Court decision on the California Tidelands Case, the federal government in the name of "national defense" or "conservation" could seize without recompense any private or state property it wishes. The state governments are fully capable of administering the leasing of oil under these lands, under sound principles of conservation, as laid down by the Interstate Oil Compact, and with far less red tape and administration cost than the federal government. If the tidelands deal is put over, oil men will really have the government in their hair.

The fight isn't over. Bills have been introduced in the 81st Congress to nullify the federal claim to the tidelands by quit-claiming them to the states. One of these might have a chance of being passed by both Houses, but I doubt if sufficient votes could be mustered to pass it by a two thirds vote over a certain Presidential veto. Bills have also been introduced to recognize federal claim to the tidelands and to establish a federal system of leasing the oil deposits under them. Determined opposition by the State's Attorney General and the oil industry should prevent passage of these bills through the Eighty-First Congress.

preserving mining claim patents

Some of you have been mining or producing oil on government-owned lands. You know that in the early days in the West when all mining was metal mining, the old Spanish mining laws became the basis of our mining laws. When a prospector discovered evidence of a metalliferous deposit, he staked out a mining claim which he could hold rights to as long as he did his yearly assessment work. Later, he could patent his claim and it became his in fee simple. Those mining laws took no thought of nonmetallic minerals and fuels, and by the time they became worth mining in the West the miners, in the eyes of the federal government, could no longer be trusted to own them, and a system of government leasing on a royalty basis was started. In the 1930's, every obstacle possible was thrown in the way of both mineral and oil leasing and patenting metalliferous deposits by the Government Land Office, now the Bureau of Land Management, and determined efforts were made to put metalliferous mining on the leasing system. Only hard fighting by the mining industry has preserved the mining claim patent system, but try to get a mining claim! Only a big mining company can afford the endless litigation and red tape necessary, and it may take ten years to get a patent. With the great need for minerals, oil, and gas that has developed during and since the war, the attitude of the Bureau of Land Management towards the leasing system is slowly becoming liberalized but not towards the system of patenting metalliferous deposits. One favorable indication is that the Bureau of Land Management has recently added trained mining men to the staffs of several of its district offices in the West.

(*Continued on p. 40*)

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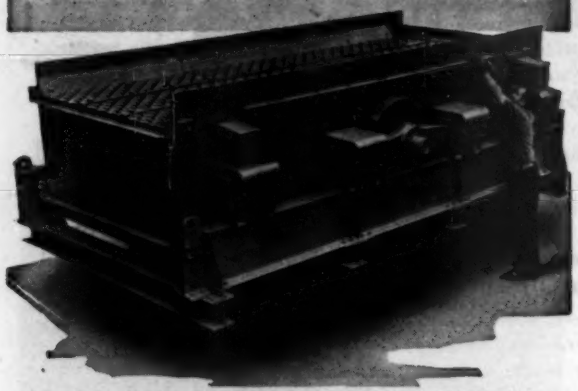

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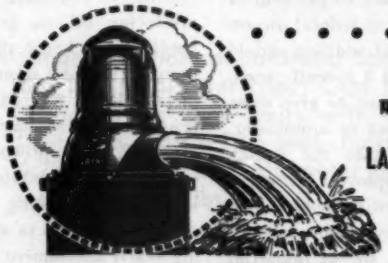

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(*Continued from p. 39, Sect. 1*)

Please understand I am not talking about the Geological Survey and the Bureau of Mines of the Department of Interior, which are doing excellent fact-finding and research work and so far have expressed little or no desire for federal control of the mining industry.

beware of federal aid

You have heard much of the need for federal aid to the mining industry. During the war we had the premium price plan for paying price bonuses to small and marginal producers of copper, lead, and zinc. It produced some much-needed metal. The submarginal mining districts and the small miners of the West want it back and bills have been introduced again in this Congress to revive it in some form and extend it to all strategic and critical minerals. I say to you, "beware of the Greeks bringing gifts." If you want it enough to have a bureaucrat telling you how you shall run your mine and how much profit you shall make, go after it. Remember, he has probably never heard of mineral depletion allowances and will think that any financial returns, over and above mining costs, are profits.

mine taxation and SEC

The federal aids really needed by the mining industry are realistic income tax provisions that will allow deduction of prospecting and development expenses instead of capitalizing them, a better equalization of profit and loss years with "carry back" and "carry forward" provisions, elimination of double taxation of dividends, and more realistic Securities Exchange Commission laws that will give some incentive for risk capital to enter the field of new mining enterprises. Canada has far better laws in this respect than we do and is reaping the legitimate tax profits on new successful mining enterprises, instead of "killing the goose that lays the golden egg."

industry is gathering its forces

The mining and oil industries are showing some signs of trying to comb the government from their hair. The American Mining Congress, the American Petroleum Institute, and the Independent Petroleum Association of

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Write for Bulletin No. 482

DENVER, COLORADO, U.S.A. (CABLE MORSE)

America are all doing good work, as are the industry councils—mineral, coal, and petroleum — appointed by Secretary Krug to advise him on policies for the Department of the Interior. The Petroleum Industry Advisory Council recently brought forth a National Oil Policy for the United States that points out the dangers the oil industry faces.

These dangers are: federal control in various forms and disguises; attempts to break up the oil industry into separate parts of production, transportation, and distribution; regulation by the Federal Power Commission of the natural gas industry in the gathering and end-use of natural gas, instead of its legitimate function of interstate transportation; labor laws that will put labor in control of management; and encouragement of various forms of co-operatives, that, free of taxation, are competing with private industry.

The 79th and 80th Congresses saw, but took no action on, bills for federal regulation of the cutting of timber on private lands. If any of your companies own forest lands for the mineral or oil reserves under them, I advise you to see to it that good forestry practices are put into effect on these lands. Not only will reforestation, protection against forest fires, and selective cutting pay dividends, but they will take away the justification for federal control.

freedom, or Santa Claus?

Write to your Congressman. But ask him for one of two things. Ask him to do all in his power to cut down wasteful government spending and to keep the government out of your hair. Or ask him to start a new project to replace the statue of freedom atop the Capitol dome with one of Santa Claus, the new symbol of American political thinking.

Manufacturers News

For rock dusting at the working face, the new MSA "FaceDuster" with its minimum weight and high pressure features is the newest rock dust distributor produced by the Mine Safety Appliances Co. The FaceDuster can be mounted permanently on drill trucks or cutting machines.

SuperDuty DIAGONAL DECK No. 6 CONCENTRATOR TABLE

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MINE SUPERINTENDENT, young, some experience in open-cut mining and underground exploration and development. Position permanent. Salary open, plus bonus, traveling expenses and living quarters supplied. Preferably single status at first. Colombia, S. A. Y2096.

FIELD MEN, preferably mining geology graduates, for geophysical surveys. Must have magnetic and electrical experience on mining projects. Considerable traveling. United States and Canada. Y2232.

CONSULTANT, MINING ENGINEER, to work part time. Must have 5 to 10 years' general knowledge of mining, plus general business experience for company buying ore and financing mining properties. Salary open. New York, N. Y. Y2241.

MINING ENGINEER, preferably single, at least two or three years' experience on underground engineering work including mapping, to do engineering work, keep maps up to date, and assist in monthly reports from the property. $3600 to start, plus room, board and transportation. Central America. Y2291.

ENGINEERS. (a) Mining Superintendent, 35-45, at least five years' supervisory experience including mine development work for feldspar, tin and gold project. $6000 to $7200. (b) Chemical Assayer, some metallurgical accounting experience, to take charge of sampling and laboratory analyses of mine ores. $4200. South Dakota. Y2299C.

CHIEF ENGINEER, 35-45, to take charge of all maintenance and mining operations for several widely scattered coal mines. Must have previous coal mining experience. $8000 to $12,000. South. Y2304.

MINE MANAGER, mining graduate, to take charge of mining and milling operations of feldspar development. Must have had previous feldspar experience. Small operation. Salary open. East. Y2319.

Men Available

MINING ENGINEER-GEOLOGIST, administrative and supervisory experience in gold, lead-zinc, coal. Exploration and development, United States and Alaska. Can assume full responsibility for organization of new project or existing operation requiring direct supervision. Domestic or foreign. Family quarters within reasonable time. 39, married, 2 children. M-423.

CONSULTING MINING ENGINEER, M.AIME, MIMM, MCIMM. Over 25 years' sound experience operation and exploration in British Columbia with important established concerns. Available June, 1949, to direct substantial exploration program, examine properties, supervise development work in B.C. for financially competent interests. Consulting basis or retainer with participation. M-424.

MINING ENGINEER, PILOT, recent graduate, degree from reputable school, 28, single. Nine years' flying experience, commercial license. Will make Cessna 140 available for company interests and equip with floats if desired. Would like position where flying experience and engineering training can be combined to advantage of employer. M-425.

MINING AND CHEMICAL ENGINEER, B.S. in both. Registered in chemical. Some formal training in civil engineering and law. Six years' varied experience including research, design, construction and operation in connection with inorganic processes. Veteran, married, one child. Age 29. Desires position with progressive organization as executive assistant or engineer. M-426.

MILL SUPERINTENDENT - MILL METALLURGIST, 44, married, B.S. in mining engineering, registered metallurgical engineer. Wide experience as operator, superintendent and in original research in complex lead-zinc-gold-silver-copper, gold and non-sulphide copper silver. Seeks permanent connection with responsibility, Southwestern U. S. or Mexico. M-427-475-E-6-San Francisco.

DREDGE SUPERINTENDENT, 29, single, 8 years' experience construction, operation, and administration of gold, platinum and tin dredges. Available after June first. M-429.

OPPORTUNITIES

CHEMIST-ASSAYER, college graduate, competent, experienced in fire assaying and wet determinations of lead, zinc, copper, gold, silver, tin, tungsten, bismuth, antimony, etc., ores and concentrates, in charge laboratory employing twenty workmen and handling about 9000 assays monthly, standard three-year contract, working knowledge Spanish essential, base salary $4,200 yearly plus bonus one month, single status or if married single status for six months, free transportation to Bolivia by air for employee and wife, free living quarters, four weeks' vacation yearly.

Box E-17—MINING ENGINEERING

Equipment

Fairbanks, Morse & Co., Chicago, has announced a compact gear motor with axial air gap. It comes in ¾ to 10-hp. sizes.

The Chicago Pneumatic Tool Co., New York, has announced a new CP-55 diamond drill. It has a rated capacity of 500 ft. and weighs only 155 lb.

The Baker Industrial Truck Division of the Baker-Raulang Co., Cleveland, announces the Baker Clamp Truck which utilizes hydraulically operated clamp arms to grip the load for lifting and transporting bulky items. Material handling is speeded because need for loading onto skids or pallets or for adjusting grabs, hooks and slings prior to moving is eliminated.

Worthington Pump and Machinery Corporation announces a new handy selection chart on Worthington water-cooled air compressors. The chart simplifies selection of proper size compressor for average industrial use, with quick comparison between discharge pressure pounds per square inch gauge, and piston displacement cubic feet per minute, and shows recommended compressor bore and stroke in inches.

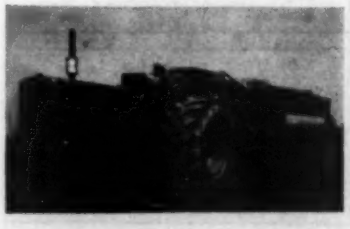
A new 15-ton Trolley-type Mine Locomotive, rated at 190 hp., 250 or 500 volts, has been announced by General Electric's Locomotive and Car Equipment Divisions. Smoothly streamlined, it features increased

safety for operators due to its high rounded end frames of heavy steel plate. Rated drawbar pull of the new unit is 7500 pounds, with a maximum pull limit of 9000 pounds. Speed at the rated drawbar pull is eleven miles an hour, which makes the locomotive well adapted to modern haulage requirements.

Front and back views of new Link-Belt "H5" High-Speed Elevator Bucket

High-speed Elevator Bucket

Link-Belt Co. has designed a new, high-speed elevator bucket embodying all the essential basic principles for high-speed operation to attain maximum capacities in handling free-flowing materials, especially grain products. It is also recommended for handling other light weight, fluffy, granular, or powdered fine free-flowing materials which are not excessively abrasive.

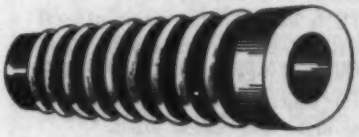


E-35 Tournahopper

For bottom-dump hauling, R. G. LeTourneau, Inc., Peoria, Ill., has announced the addition to its line of earthmoving and materials handling equipment of the E-35 Tournahopper. The Tournahopper has an exclusive dumping action. The bottom dump doors are designed to operate in a manner similar to a clamshell, swinging upward along the outside of the Tournahopper bowl as they open. Positive electric control of the self-cleaning doors permits controlled ejection by opening the doors to any desired width.

Unusual Belt Conveyor

The Goodyear Tire & Rubber Co., Akron, Ohio, has designed and built a belt to carry refuse from a central coal cleaning plant in a valley to a spoil pile over a hill 1500 ft. away. This belt is now in operation at the new cleaning plant of the U. S. Coal & Coke Co., a subsidiary of U. S. Steel Corp. The 30-in. wide steel cable belt spans a deep gorge via the suspension bridge, which at one point is over 300 ft. above ground. When operating at capacity, the belt will transport hourly 350 tons of shale, rock, slate, and other coal-cleaning spoil, discharging 486 ft. above the loading point. Belt speed is 400 ft. a minute.



Burnishing Tool

An automotive manufacturer states that this Carboloy solid carbide "bar" —measuring 1¼ in. long by ½-in. in dia.—burnished more than 5,000 piston pin holes in cast iron pistons without requiring maintenance. The chrome plated burnishers formerly used for this operation ran only between 50 and 100 pistons before they wore so much that they had to be discarded.

Bulletins

Magnetic Pulleys. The Stearns Magnetic Mfg. Co., Milwaukee, describes a new line of permanent magnetic pulleys in Bulletin 350. It contains features, illustrations, specifications, dimensions, capacities and typical applications. Pulleys are non-electric, require no wiring or electrical connections and can be used under all atmospheric and operating conditions for automatic removal of tramp iron, reclamation of secondary metals, and for separating magnetic and non-magnetic materials.

Worm Gear Speed Reducer. The Cleveland Worm & Gear Company's SPEEDAIRE saves space, weight, and money. Because it is fan-cooled, SPEEDAIRE will do more work and

(*Continued from p. 39*)

can be installed economically on many applications where other types have been used heretofore, giving you the advantages of a compact right-angle drive. Low height and portability are musts in a mine conveyor. This equipment builder meets both requirements. For full description, write for Catalog 300.

PORTITE. The distributors of PORTITE, Hopper Products, Inc., New York, offer not only a unique and superior product, but full cooperation in working out its most profitable applications. PORTITE is a long-chain, high-molecular, neutral compound in aqueous solution. It is a controllable air entraining agent, a wetting or dispersing agent, and a promoter of cement hydration. PORTITE is indicated for use in general concrete, concrete made with lightweight aggregates, cement plaster, mortar concrete masonry, precast concrete units, and cement grout.

Cages and Skips. Bulletin #A-457, issued by Vulcan Iron Works, Wilkes-Barre, Pa., not only illustrates and describes their principal types of cages, skips, and gunboats but also contains illustrations and descriptions of six recent Vulcan electric hoists—all different and all embodying distinctive features to meet specific requirements. On pages 18 and 19, are illustrations of Vulcan all-casteel sheaves, with different types of plain and anti-friction bearings; also Vulcan slope rollers with anti-friction bearings. The constantly increasing emphasis on safety in hoisting equipment should make this bulletin interesting to many mining companies.

Personals

Seward T. Salvage has been made sales promotion manager of *The Timken Roller Bearing Co.* with headquarters in Canton, Ohio.

J. R. Thompson, formerly manager of the Denver district of industrial products sales for *The B. F. Goodrich Co.*, has been named manager of flat belting, conveyor, elevator and transmission belting, and *Paul W. Van Orden* manager of "V" belts and packing. Mr. Van Orden has been with the company for 21 years, all of which have been in belting sales and engineering.

(*Continued on p. 41*)

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W. E. Gahl has been appointed chief engineer of *Templeton, Kenly & Co.*, Chicago, manufacturers of Simplex Jacks.

E. L. Klingler will direct the sale of Wickwire rope for the *Colorado Fuel and Iron Corp.* in the Mid-Continent area. Mr. Klingler has been engaged in the wire rope industry, including production, engineering, and sales for 19 years.

D. D. Morris, formerly general superintendent of the Alberta Nitrogen Department, Cominco's chemical operations in Calgary, has been appointed general superintendent of the Research and Development Division of *The Consolidated Mining and Smelting Co.* of Canada, Ltd.

The Eagle-Picher Co. has appointed *Dr. A. Paul Thompson* as director of research. Widely known in the chemical, ceramic, and metallurgical research fields, Dr. Thompson comes to Eagle-Picher from the Mellon Institute of Industrial Research where he has held a Senior Fellowship since 1932.

Ralph B. Utt, general sales manager of *Western Machinery Co.*, recently returned from an extended tour of mining properties in Europe and Africa. He was able to observe at first hand the rehabilitation of mining production which is being made possible by the work of ECA under the Marshall Plan.

James W. Raynolds, former vice-president and director of the Sun Chemical Co. of New York, has joined the Chemical Department of *General Electric* as sales manager of silicone products, according to an announcement by John A. Zellhoefer. With headquarters at Waterford, N. Y., Mr. Raynolds will have commercial responsibility for G-E silicone gum, oils, emulsions, greases, resins, and water repellents.

The Hercules Powder Co. recently announced the appointment of *Milo A. Nice* as assistant manager of its Explosives Department's Technical Service Division. *Arthur H. Sibley* will succeed Mr. Nice as assistant manager of the Explosives Department's New York office. During the past 19 years, Mr. Nice has specialized on the technical and blasting problems in connection with quarrying, mining, construction, and other explosives consuming industries.

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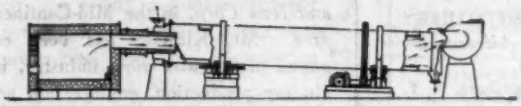

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Advertisers' Index

SECTION 1 — Front and Back

Aero Service Corp. ..... *
The Aitkin-Kynett Co.

Allen-Sherman-Hoff Co., Third Cover
Eugene A. Holland

Allis-Chalmers Mfg. Co. 4, 37
Compton Advertising, Inc.

American Cyanamid Co. ..... *
James J. McMahon, Inc.

American Manganese Steel Div., American Brake Shoe Co. 33
Advertising Producers Associated

American Ore Reclamation Co. *

American Paulin System 41
Columbian Adv.

Anaconda Copper Mining Co. *
Elkington & Co.

Berger & Sons, Inc., C. L. ..... *
DuFine-Kaufman, Inc.

Cate Equipment Co. ..... *
Cooper & Crowe

Christensen Diamond Products Co. ..... *
Axelsen Adv. Agency

Clarkson Mfg. Co. ..... *
Eggers-Rankin Adv. Service

Climax Molybdenum Co. 39
Rowlinson-Broughton

Colorado Fuel & Iron Corp., Wickwire Spencer Steel Div. ..... *
Fuller & Smith & Ross, Inc.

Colorado Iron Works Co. ..... *
Shaw Advertising

Deister Concentrator Co. 41
Louis B. Wade, Inc.

Denver Equipment Co. ..... *

Dorr Co., The ..... *

Dow Chemical Co., The (Great Western Div.) 36
MacManus, John & Adams, Inc.

Eimco Corp., The ..... *

El-Tronics, Inc. 32
Packard Advertising

Euclid Road Machinery Co. ..... *
The Bayless-Kerr Co.

Flexible Steel Lacing Co. ..... *
Kreicker & Meloan, Inc.

Gardner-Denver Co. 34
The Buchen Co.

General Electric Co. ..... *
G. M. Basford Co.

Hardinge Co., Inc. 46
The W. H. Long Co.

Harnischfeger Corp. ..... *
The Buchen Co.

Hendrick Mfg. Co. ..... *
G. M. Basford Co.

Hercules Powder Co., Inc. 11
Fuller & Smith & Ross, Inc.

Hercules Powder Co. (Flotation) 35
Fuller & Smith & Ross, Inc.

Ingersoll-Rand Co. 1
Rickard & Co.

International Nickel Co., Inc. 2
Marschalk & Pratt Co.

Jones & Laughlin Steel Corp. 5
Ketchum, MacLeod & Grove, Inc.

Joy Mfg. Co. (Sullivan Machinery Div.) ..... *
Walker & Downing

Layne & Bowler, Inc. 40
O'Callaghan Adv. Agency, Inc.

Liege International Fair ..... *
Dorland, Inc.

Link-Belt Co. 6
Don Proctor Adv.

Longyear Co., E. J. ..... *

Merrill Co. 40
The McCarty Co.

Mine & Smelter Supply Co. 12
Shaw Advertising

Mine Safety Appliances Co. Back Cover
Walker & Downing

Morse Bros. Machinery Co. 41

Nordberg Mfg. Co. 8
Russell T. Gray, Inc.

Oliver United Filters Inc. ..... *
Sanger-Funnell, Inc.

Phelps Dodge Corp. 38

Sauerman Bros., Inc. 46
Symonds, MacKenzie & Co.

Sheffield Steel Corp. ..... *
R. J. Potts-Calkins & Holden Adv.

Texas Gulf Sulphur Co. ..... *
Sanger-Funnell, Inc.

Tyler Co., W. S. 40

Union Pacific Railroad ..... *
The Caples Co.

Wellman Engineering Co. 7
The Griswold-Eshelman Co.

Western-Knapp Engrg. Co. ..... *
Walther-Beland Associates

Wheel Trueing Tool Co. Insert 9, 10
Clark & Rickerd, Inc.

Willfley & Sons, Inc., A. R. 2nd Cover
Ed. M. Hunter Advertising

Wilmot Engineering Co. ..... *
Wilbur A. Myers

Worthington Pump & Machinery Corp. ..... *
James T. Chirurg Co.

Yuba Mfg. Co. ..... *
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* Previous Issues

XUM